INFANTS' RESPONSES TO TEMPORALLY REGULAR EVENTS AND THEIR OMISSION

By

MARGARETE BOETTCHER DAVIES

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To Tom, with love and gratitude

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Margarete Boettcher Davies

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Major Department: Department of Psychology

Infants one to two months of age were presented with pulsed stimuli that came on and off at regular 20 second intervals with omissions of these events occurring as test trials. Following initial test trials, an uninterrupted series of trials was provided to heighten the chance for an anticipatory heart rate response to develop. Finally, there was a frequency change to examine the phenomenon of dishabituation and its effect on timing. The stimuli employed were pulse trains consisting of 70 dB (A) sine waves at either 1000 or 1600 Hz that came on and off at 500 millisecond intervals. This pulse train was alternately turned on and off each 20 seconds.

While the infants exhibited a large orienting response to pulse train onset, there was virtually no response to pulse train offset. The implications of this result are discussed in the context of orienting theory. The time-locked response, i. e., the response that occurs at and following stimulus omission, was rather weak compared to a previous experiment by Davies and Berg using continuous stimuli; it occurred predominantly to the first of two consecutive event omissions, and the deceleration was rather irregular in shape. This outcome supports Thomas and Weaver's theory which proposes that higher levels of information processing disrupt timing. Evidence for anticipatory responding was weaker than that for a time-locked response. This is consistent with the literature on this age group. The weak anticipatory response was disturbed by the change in frequency. Dishabituation was significant only for a frequency change from high to low.

CHAPTER I

INTRODUCTION

The Importance of Rhythms and Timing

For animals and humans alike, the ability to estimate time intervals is adaptive. Examples ranging from mating and predatory behaviors, where temporal coordination leads to greater efficiency, to skills which usually depend on high levels of temporal accuracy attest to the importance of timing capability. Organisms' ability to judge time intervals is often hypothesized to be based on physiological oscillations (e. g. Ashton, 1976). Rhythmic oscillations have been found at all physiological levels in such astonishing numbers that three journals deal with them exclusively (Chronobiologia, the International Journal of Chronobiology, and the Journal of Biological Rhythms). Though the most obvious example is the sleep-wakefulness rhythm with its far reaching physiological effects, oscillations have been found at all physiological levels (Conroy & Mills, 1970, Palmer, 1978). The ubiquity of physiological rhythms suggests that rhythmic phenomena should also be apparent at a psychological level. Several behavioral rhythms have already been found. Performance, for example, cycles at approximately 90 minute intervals

during waking hours, appearing to be an extension of the 90 minute REM cycles occurring during sleep (Lavie, 1982). Other examples include rhythms in play (Thomae, Erftmann, Lehr, & Schapitz, 1972), intrinsic temporal patterning in the spontaneous movement of neonates (Robertson, 1982), and rhythms in skilled performance (Shaffer, 1982). Thus, the diversity of physiological rhythms seems also to be evident among psychological phenomena. The aim of the present dissertation is to investigate timing mechanisms during infancy and the possible influence rhythmic aspects of a stimulus may have on simple information processing.

The Special Importance of the Time Dimension for Infants

A variety of findings suggests that the time-dimension is more important during infancy than during adulthood. Infants display rhythmic behaviors that disappear later in development (Wolff, 1967); the infantile rhythmic sucking pattern, for example, cannot be reproduced by adults, but may reoccur in cases of degenerative central nervous system disease (Wolff, 1967, p. 214). Other rhythms that occur only in infants and have a periodicity similar to the one of the sucking rhythm include crying (Wolff, 1967) and scanning in the dark (Haith, 1980). This ontogenetic development parallels changes across phylogenetical levels: lower animals tend to exhibit more periodicities than higher animals (Richter, 1965).

Data from conditioning studies indicate that young infants perform at least as well if not better than older children or adults on time estimation tasks. Two-month-old infants gave a significant heart rate response to the omission of a stimulus after only four 20 second intervals had been presented while the qualitatively different response of 7-month-old infants did not reach significance with so few intervals (Davies & Berg, 1983). The response of the younger group was time-locked; i.e., it occurred at the time the stimulus would have occurred, while the older group showed, later in the test session, anticipatory responding. Since different mechanisms may underly the two kinds of response, no definite conclusion can be drawn as to which age group is more accurate in timing. Nonetheless, the data make it evident that young infants are able to very quickly detect and reflect an externally imposed interval in their physiological activity. Brackbill, Fitzgerald, and Lintz (1967) conditioned pupillary constriction and dilation to time and to a tone in adults and in infants in an age range from 26 to 86 days. To condition pupillary responses to time, the off/on light was alternated in a 20 seconds off, 4 seconds on (constriction training) or 20 seconds on, 4 seconds off (dilation training). To condition pupillary response to tone, a delay conditioning paradigm was used with tone onset preceding a 4 second light change by 1.5 seconds. Variable intertrial intervals were used. For the

infants, pupillary dilation and constriction were successfully conditioned to time but not to the tone. The adults, on the other hand, could be conditioned to the sound but not to time. The authors' interpretation is that time perception may be already fully developed in young infants, and that this ability may be impaired rather than enhanced during later development. A problem with this study is that the pupillary diameter values of the 4 seconds immediately preceding the test trials were used as baseline values. If there was anticipatory dilation and constriction in the adult group, as Davies and Berg's (1983) data suggest there may have been, then a temporal conditioning effect would have been masked. A comparison of the baseline values of the time condition versus the sound condition from Table 7 of the Brackbill et al. (1967) monograph is suggestive of such an effect. Although a superiority in timing ability on the part of young infants cannot be unequivocally inferred from either the Brackbill et al. (1967) or the Davies and Berg (1983) studies, a study by Hoffman, Cohen, and DeVido (unpublished manuscript) gives more conclusive evidence for more optimal and, in some respects, more accurate timing on the part of infants 7 to 60 weeks old. In a delay conditioning paradigm, a tap to the glabella was preceded by a 500 msec tone. Conditioned anticipatory blinks occurring during the tone period had a longer latency with infants than adults. As a consequence, for the infants but not

adults, the tap to the glabella occurred when the neural mechanisms for a subsequent blink were still in a relatively refractory state. This had the effect of reducing the subsequent blink, elicited by the tap, which the authors interpret as greater efficiency (presumably because less energy was expended) on the part of the infants. The authors make a claim for greater accuracy on the part of the infants, since in their paradigm anticipation too far in advance of the UCS may be seen as disadvantageous.

Caution is warranted when comparing the Hoffman et al. results with the two temporal conditioning studies described earlier since it differs substantially in the temporal interval assessed and the age of the subjects tested. Nonetheless, these few data available attest to the remarkable timing capabilities of infants.

The temporal dimension spans a wide range of infant behaviors, from simple physiological reflexes to highly organized social behaviors. Not only do infants perform well in timing tasks, they also seem to enjoy the temporal aspects of their lives. The time dimension is important in many infant games (Miller & Byrne, 1984) as well as in soothing infants (Ter Vrugt & Pederson, 1973). Davies and Berg's (1983) experiment indicates that young infants may process time qualitatively differently than older infants and adults. While older infants and adults react with an anticipatory heart rate response to a predictable temporal

interval (Davies & Berg, 1983, Johnson & May, 1969), younger infants tend to react with a time-locked response, i. e., a response occurring exactly when the omitted stimulus should have occurred (Clifton, 1974, Davies & Berg, 1983, Stamps, 1977). The response of the younger group may constitute a precursor or a necessary component upon which the anticipatory response of older infants and adults could be based. The many different theories on timing that have been proposed may be put to a better test with infant subjects because the adult or even the preschooler exhibits behaviors too complex to clearly reveal the underlying mechanisms (Ashton, 1976).

Focus of this Dissertation

The main topic of this dissertation is to investigate the characteristics of the time-locked response which appears during the presentation of significant events regularly spaced in time. Developmentally, the time-locked response seems to be the earliest occurring response to time (Clifton, 1974, Davies & Berg, 1983), and theoretically the most primitive one: the only components necessary are an oscillator and a counting mechanism. For the developmentally later occurring anticipatory response (Davies & Berg, 1983), on the other hand, at least a subtracting mechanism is needed as well, even though the possibility exists that anticipation works by a completely different mechanism. Developmental and stimulus

determinants of the anticipatory response will be a secondary topic of this dissertation. In addition, the impact on the timing process of a rhythmic, pulsed stimulus and of a qualitative change in that stimulus is explored. Finally, cardiac orienting to onset and offset of pulsed stimuli is assessed.

The Time-locked Response

The time-locked response has been shown to occur after only very few stimulus presentations (Davies & Berg, 1983), an impressive accomplishment on the part of the 2-month-olds. Since this finding is so extraordinary, the first step of this dissertation is to replicate and extend the 1983 results with a different stimulus event. To this end, a pulse train--instead of a continuous stimulus as in Davies & Berg (1983)--is employed. In the earlier study a continuous tone was alternately turned on and off at 20 second intervals; in the present study the pulse trains started and stopped at 20 second intervals, resulting in a somewhat more complex temporal situation. The pulses within the trains went on and off at 500 millisecond intervals. Thus during the pulse trains there was a regular rhythm at a frequency that occurs in several spontaneous behaviors of young infants, as for example sucking or crying (Wolff, 1967). In younger infants (under approximately 5 months), pulsed stimuli are more likely to elicit attention as measured by the size of the orienting response (Bohlin,

Lindhagen, & Hagekull, 1981). The difference between the stimuli that are used in the present study and those used in Davies and Berg (1983) can be summarized as follows: in the present study, the stimuli are more complex, since two temporal intervals are superimposed upon each other (.5 seconds and 20 seconds); the rhythm that is superimposed on the 20 second intervals matches the frequency of many spontaneous behaviors in young infants (Wolff, 1967); and the stimuli are more effective in eliciting young infants' attention (Bohlin et al., 1981).

If the 2-month-old infants again exhibit a time-locked response, this result would argue for the pervasiveness of the phenomenon. If such a phenomenon occurs to two different stimuli, the implication is that it may have importance for a larger set of situations in the daily life of the infant. If the time-locked response is disrupted by this more complex stimulus, it would be an important consideration in hypotheses concerning the underlying mechanism. Disruption of the time-locked response by stimuli that have a high information value would be consistent with Thomas and Weaver's (1975) theory of a timer and a cognitive processor between which attention is shared. Presumably, a complex stimulus would put a greater demand on the cognitive processor, and result in reduced capacity for the timer. Disruption of timing by a more complex stimulus would also be in agreement with the data of

Brackbill et al. (1967), where infants could be conditioned very easily to one time interval, but it was impossible to condition them to a pattern of intervals. Even though the primary focus of this dissertation is the time-locked response, an investigation of the time-locked response cannot be entirely separated from considerations for the anticipatory response.

The Anticipatory Response

The anticipatory response seems to be the mature response, since it has been found in adults (Johnson & May, 1969) and older infants (Davies & Berg, 1983), while in younger infants anticipatory responding either could not be elicited (Clifton, 1974, Davies & Berg, 1983), or the evidence for anticipatory responding was rather weak (Leavitt, Brown, Morse, & Graham, 1976, Stamps, 1977, Stamps & Porges 1975). Clifton (1974), Stamps (1977), and Stamps and Porges (1975) used newborns in their studies, Leavitt et al. (1976) used 6-week-olds, and Davies and Berg (1983)used 2-month-olds. In the Davies and Berg (1983) experiment, the conditions for an anticipatory response to develop were far from ideal since the test trials (stimulus omissions) were inserted early and fairly frequently, which can disrupt the overall perception of the timing pattern. While results from previous experiments show that anticipatory responding in newborns is questionnable at best, for 2-month-olds the issue is still unresolved. Thus the present dissertation

included a more extended and uninterrupted series of intervals (see Figure 1) so as to more effectively address the question whether 2-month-olds are capable of developing an anticipatory response.

The Impact of Temporal Variables on the Processing of Information

Young infants tend to exhibit a larger orienting response to pulsed stimulation than to continuous stimulation (Bohlin et al., 1981), an effect that disappears with age (Graham, Anthony, & Zeigler, in press). Also, pulsed stimulation seems to be advantageous for dishabituation in young infants (Clarkson & Berg, 1983). Reports on the response to the offset of pulsed stimuli are somewhat conflicting. Clifton & Meyers (1969) in an experiment with four-month-olds with 300 Hz square wave stimuli found a significant decelerative offset response only to continuous but not to pulsed tones. This finding is in agreement with Rewey (1973) who used a pulsed 2-tone combination and a continuous single sine wave. Berg's (1972) data on 4-month-olds using pure tones of 1100 and 1900 Hz pointed in the same direction, but the effect was not statistically substantiated. In a study on 6-week-old infants (Leavitt et al., 1976), no response to the offset of 162 second presentation of pulsed sine waves that alternated in frequency was reported, but a significant heart rate deceleration to the offset of 60 second trains of

speech syllables (500 msecs on, 500 msecs off) was found. Bohlin et al. (1981) did not find an offset response to pulsed or continuous tones in 13 to 18 week olds; however, an offset response to continuous but not to pulsed tones was found in a group of 26 to 35 week olds. There was some suggestion in the data that with repeated stimulus presentations the younger infants may have tended to respond to the offset of continuous stimuli. Because the stimulus duration was only 10 seconds in this experiment, the authors suggested that the minimal duration to produce offset responses may be shorter for continuous than for pulsed tones. This implies that offset responses to pulsed stimuli might be observed if the pulse train is sufficiently long. The present dissertation used pulsed pure tones which stayed on for 20 seconds with a 20 second interstimulus interval (ISI). At one point, the pulses stayed on for 60 seconds (see Figure 1). Thus, the duration hypothesis of Bohlin et al. was tested to a certain extend. For comparison, data were available from a similar previous experiment (Davies & Berg, 1983) using continuous stimuli.

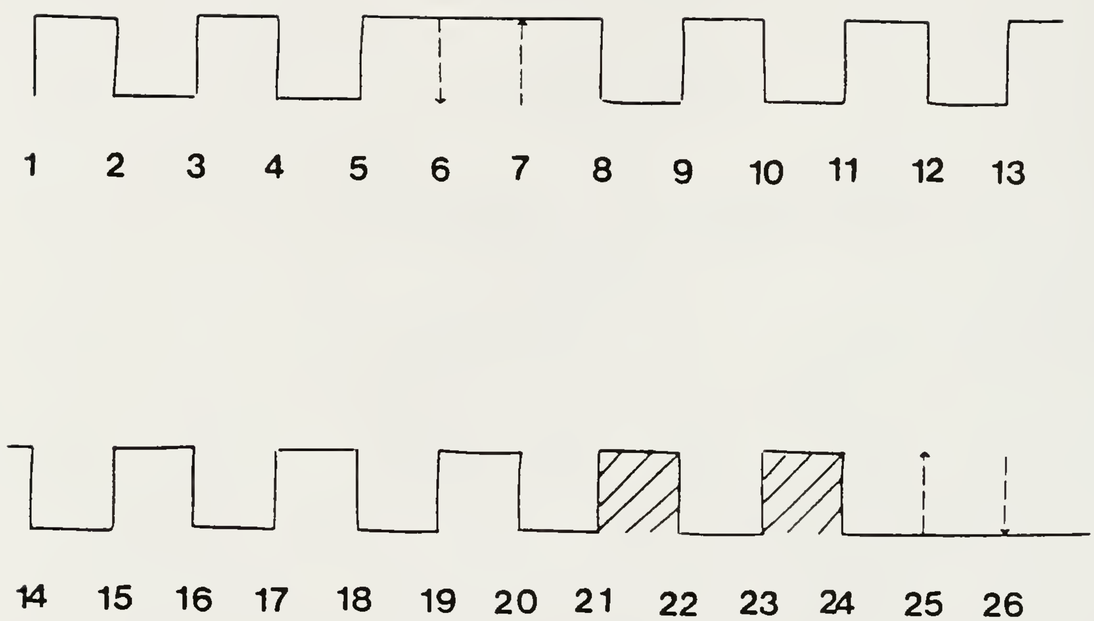

Figure 1. Pattern of pulse train onsets and offsets for the 26 trials. Cashed arrows indicate where onsets (upward arrows) or offsets (Downward arrows) were omitted. Cross-hatched areas indicate the change in tone frequency.

CHAPTER II

METHOD

Subjects

Subjects were obtained through telephone solicitation to the parents of infants born in Alachua County, Florida. Upon the parents' arrival, the study was explained to them in more detail, and they were asked to sign an informed consent form (Appendix A). In addition, the parent(s) filled out a medical questionnaire (Appendix B) to screen the infants for health problems. Parents were paid $5.00 for each visit of their child.

Infants with an age range from 55 to 92 days and a mean age of 68.1 days were tested. To obtain a total of 20 usable subjects, 70 had to be tested. Of these, 41 were eliminated because of fussing or sleepiness, three for health problems, two for pre- or postmaturity, three due to equipment failure, and one for experimenter error. For an analysis of the first seven trials, the sample consisted of 10 subjects aged 68 days or older and 10 subjects younger than 68 days with average ages of 75.7 and 60.5 days respectively. Each age group contained five males and five females with two males and three females listening to 1000 Hz tones first and three males and two females listening to

1600 Hz first. Only eight subjects with an average age of 70 days maintained a satisfactory state for the remaining trials (trials 8 through 26), of which seven were also judged satisfactory for trials 1 to 7.[1] Of the eight subjects, four were male and four were female. Of the male subjects, three started the session with 1600 Hz and one with 1000 Hz, while one female subject started with 1600 Hz and three female subjects started with 1000 Hz.

Stimuli

Sine wave tones with a pulse rate of 500 milliseconds on / 500 milliseconds off and a 25 millisecond rise and fall time came on at 40 second intervals and stayed on for 20 seconds. Onset and offset of a pulse train were considered separate trials. Pairs of stimulus onset and offset omissions were created by allowing the pulse train to either stay turned on or remain turned off for one complete tone on and off period (see Figure 1). Thus, the test period resulted in a 60 second tone on period in the cases of the initial test (trials 6 and 7) and a 60 second silent period in the case of the final test (trials 25 and 26). The tones were 70 dB (A) over a background level of 22 dB (A) and 1000 Hz or 1600 Hz in frequency. On trial 21, the first

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[1]Data of the eighth subject were not used for analyses of the first seven trials due to excessive movement during this period.

dishabituation trial, the frequency was changed from 1000 Hz to 1600 Hz or from 1600 Hz to 1000 Hz.

Apparatus

The stimuli were generated by a Krohn-Hite Model 5300 function generator, a Wavetek Model 131A VCG Generator, or a Hewlett Packard Model 200 CD Wide Range Oscillator. The stimulus durations and ISIs were controlled by a Digital PDP8/e laboratory computer. An Iconix 6837 electronic switch set to a rise and fall time of 25 milliseconds gated the onset and offset of the stimuli. The tones were amplified by a Dynaco SCA-80 amplifier and delivered free-field through an Analog and Digital Systems Model 810 speaker which was placed facing the infant at a distance of approximately 50 centimeters inside a 1 by 1.5 meters sound attenuating chamber. Intensity levels were measured free field on the a scale of a Bruel & Kjaer Type 2203 Precision Sound Level Meter at the site of the infant's head. A Hewlett Packard 350D attenuator set was employed to achieve the intensity matching (equating for a 5 dB difference) between the two frequencies.

The laboratory assistant who stayed with the infant during testing listened to approximately 95 dB white noise[2] in a frequency range of 900 to 1700 Hz that completely masked the tones. The noise was produced by a

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[2] Since nonstandard circumaural earphones were used, the exact loudness could not be ascertained.

Grason-Stadler Model 455C noise generator, filtered through a Krohn-Hite Model 3700R filter, and amplified by a Sansui AU-517 Integrated Amplifier. It was presented through Koss PRO/4AA earphones under which the assistant wore earplugs (McKeon) in order to protect his/her hearing. Leakage of the noise through the earphones increased the level of background noise by about 2 dB.

The EKG was detected with Beckman Ag/AgCl 16 mm surface electrodes that were attached with Micropore 3M No. 1530 surgical tape, and Synapse electrode cream (Med-Tek Corporation). Respiration was recorded with a mercury filled strain gauge and a Parke Electronics model 270 plethysmograph. Both signals were amplified and recorded on a Beckman polygraph model 5411B using Type 9806A A-C couplers which also recorded a pulse marking 20 second time intervals coincident with the stimulus pattern. The polygraph output of the signals and the stimulus pulses were stored on a Hewlett-Packard 3960 Instrumentation FM tape recorder. For heart rate analysis, the EKG signals stored on FM tape were replayed and, using a shop-built peak detector to sense each R-wave, the beat to beat intervals in milliseconds were computed by a Digital PDP8/e laboratory computer. The interbeat intervals were stored on floppy discs for later analysis.

The sessions were recorded with a SONY U-matic model VO-2610 videocassette recorder with a Hitachi CCTV camera

Model HV62U and a Model ECM-150 SONY Electret condenser microphone. They were displayed for the parents on a Panasonic solid state TV Model No. TR-195MB.

Procedure

The electrodes were taped to the infant in a modified lead II configuration with the two active electrodes located approximately one centimeter above the right nipple and at the bottom of the left rib cage and the ground electrode approximately one centimeter above the left nipple. The strain gauge was stretched over the infant's stomach at waist level. The infants sat in a semi-reclining infant seat on a table with colored Christmas lights suspended from the ceiling. The laboratory assistant sat next to the infant in an angle of approximately 60 degrees at a distance of approximately 40 centimeters. A subject was tested only if he or she was in a satisfactory alert state. If the infant appeared to change to an unsatisfactory state, the assistant intervened in a subdued manner by either gently rocking the infant, stroking his/her arm, letting the infant look at his/her face, or presenting a quiet toy. The interventions were as few and as rare as possible. Since the assistant listened to noise, his/her judgement of the necessity of intervention was impaired due to the lack of vocal information. The high drop out rate of the present experiment is in part due to the resulting inability of the

assistant to adequately control the infant's state. The decision on whether to use data from an infant depended on two independent state raters who judged the infants' state from the video and audio recording. State criteria for eliminating infants were as follows: infants were rejected for fussing, i.e. when they displayed excessive movement, grimacing, restlessness, or distress vocalization, and they were rejected for sleepiness, i.e. when they made little or no movements, the breathing was very regular, and the eyes were closed or nearly or occasionally closed. If an infant became seriously upset, data from the subsequent trials were not used. If an infant became seriously upset before trial 8, the subject was not used for the study. Two trained state raters independently judged the infants' state on each trial from the videotapes. The interrater reliability for the final sample was 98% for whether a trial should be accepted or rejected. A trial was used for data analysis only if both raters judged the infant's state satisfactory.

Data Analysis

Interbeat intervals stored on floppy disks were edited for skipped R-waves, T-waves, and movement artifacts. They were then converted to average heart rate per second for all seconds of each predetermined analysis period (see results section). Analyses of orthogonal components of trends were performed with the 2V version of the BMDP statistical package. Trends of higher than cubic order are not

reported, because they are uninterpretable for these data. When main effects were reported, the Huyhn and Feldt (1976) estimator of the Box corrective adjustment for degrees of freedom was used in the calculation of the final p value in order to correct for violations of sphericity (Huyhn & Feldt, 1970). In the text, the original degrees of freedom are given.

CHAPTER III

RESULTS

The analysis was begun by establishing the response to the regular stimulus trials--the response to actual stimulus onsets and offsets. Next the response to the stimulus omissions, trials 6, 7, 25, and 26, was analyzed. Finally, the dishabituation trials and the possibility of a developing anticipatory response were examined.

Initial analyses up to and including trial 7 contained the between subjects factors of age, sex, and frequency. Age was included as a factor, because preliminary inspection of the data suggested that it might have an effect. Due to subject attrition, one of these between subject factors had to be dropped for analyses of trials later in the sequence. The factor "age" was chosen to be excluded, since the age range in this study is rather narrow.

Only eight subjects remained in a satisfactory state throughout all 26 trials. Analyses on dishabituation, anticipation, and the later stimulus omissions were done first on these eight subjects only in order to facilitate comparisons across analyses and because these subjects' data could not be influenced by earlier state changes. However,

the analyses were repeated using all subjects who were in an acceptable state on the subset of trials of interest in order to confirm the results with a more substantial N.

The length of the post-stimulus period to be examined was based on an inspection of the responses on the initial trials which revealed a large monotonic deceleration that reached its nadir around 6 seconds after onset of the stimulus trains and appeared not to entirely recover within the 20 second ITI (see Figure 2). Therefore, it was judged advisable to use a long analysis period; the longest post-stimulus interval possible under the constraints imposed by the heart rate processing software was the period from .5 seconds preceding to 15.5 following stimulus change. Anticipatory responding was analyzed over a period of 6.5 to .5 seconds preceding stimulus change, as in Davies and Berg (1983).

In the following analyses, trends of higher than cubic order are not reported since they are not easily interpretable. Results of lower order that are not directly relevant to the questions at hand, that cannot be interpreted unequivocally, or that are redundant are not mentioned in the text but are listed on table 1 in Appendix F. Several analyses yielded main effects for sex and frequency as a result of consistently higher heart rates for females than males and higher heart rates for subjects who started with 1600 Hz than those who started at 1000 Hz.

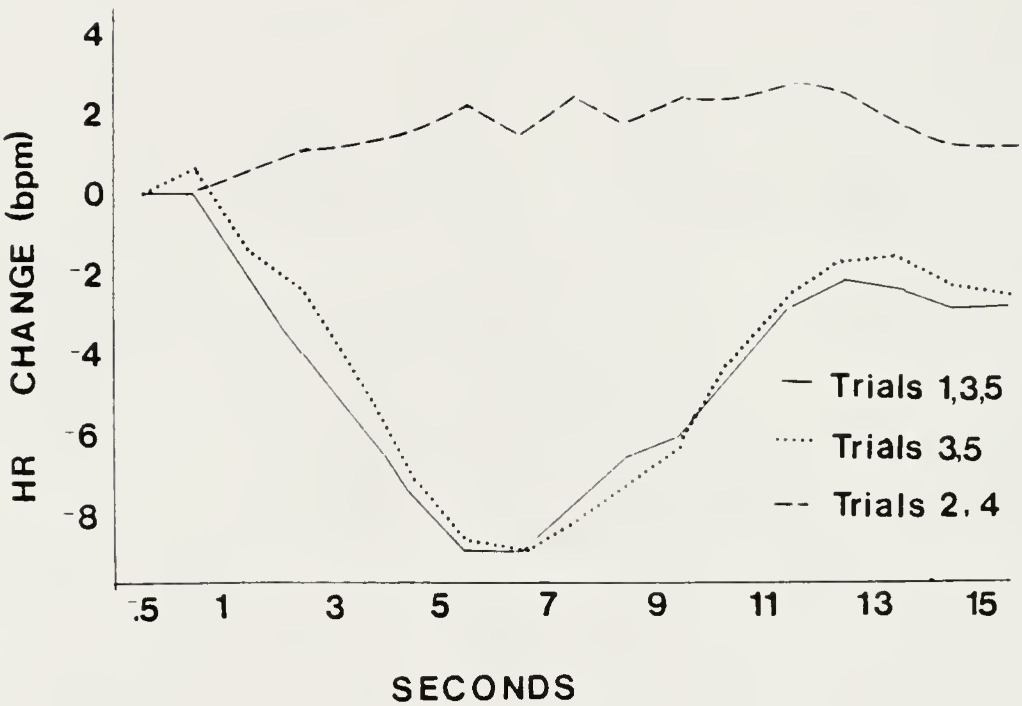

Figure 2. Averaged response over onset trials 1, 3, and 5 (solid line), onset trials 3 and 5 (dotted line), and offset trials 2 and 4 (broken line).

Since these results are unlikely to have much of an influence on the heart rate responses of principal interest here, they are only noted in table 2 in Appendix F.

Stimulus Onset and Offset Trials 1 to 5

Visual inspection of the results indicated substantial differences between stimulus onset and offset (see Figure 2). The response to stimulus onset consists of a substantial orienting response in form of a heart rate deceleration, whereas there is little response to stimulus offset, or possibly a slight acceleration. The first analysis sought to establish whether this difference was statistically significant. Trials 2 and 4 and trials 3 and 5 were combined into a block of offset trials and a block of onset trials, respectively. Trial 1 data were excluded from the onset block in order to provide a more conservative comparison of onset and offset and to eliminate any bias against offset that might result from habituation. If habituation effects occurred, the trials selected would favor offset responses. A significant on/off by quadratic seconds interaction, $F(1, 12) = 32.58$, $p < .00025$, reflected the substantially larger response to stimulus onset than offsets. These results indicated the need for separate analyses of onset and offset responses. There were also interactions marking sex: on/off by sex by quadratic seconds and also by cubic seconds interactions, $F(1, 12) = 8.8$, $p < .025$, and $F(1, 12) = 7.56$, $p < .025$, respectively. These

results indicate a sex effect for either onset or offset responses or both, and were further examined through separate analyses for onset and offset responses.

Stimulus Onset Trials 1, 3, and 5

A quadratic seconds effect, $F(1, 12) = 45.56$, $p < .0001$, which accounted for over 20% of the variance, and a cubic seconds effect, which accounted for under 4% of the variance, $F(1, 12) = 22.10$, $p < .001$ were statistical evidence of the unexpectedly large heart rate deceleration to stimulus onset.

Surprisingly, no significant trials by quadratic or cubic seconds interaction were found, indicating that significant overall habituation did not take place over these 3 trials. A linear trials effect, $F(1, 12) = 5.02$, $p < .05$ was found which in the absence of a trials by seconds interaction suggested a change in prestimulus heart rate level. Indeed, there was a slight rise in heart rate level at second -.5 from 149.83 bpm at the beginning of trial 1 to 150.35 bpm at the beginning of trial 3 to 151.42 bpm at the beginning of trial 5. Even though this difference was statistically significant, the absolute change of 1.59 bpm from trial 1 to trial 5 is so small as to make it of minor consequence with regard to effects on responses.

Some habituation effects were suggested by a significant trials by cubic seconds by sex by frequency interaction, $F(1, 12) = 5.21$, $p < .05$. It indicated that

the response developed differently over trials for different subgroups, and along with a quadratic seconds by sex interaction, $F(1, 12) = 6.67$, $p < .025$, was followed up by analyzing each sex separately.

Analyses of sex differences for stimulus onset trials 1, 3, and 5. Based on the seconds by sex interactions in the response to onset trials, these trials were reanalyzed for each sex separately with no between subject factors and only trials and seconds as within subject factors. For the male subjects, the analysis yielded quadratic and cubic seconds effects, $Fs(1, 9) = 48.5$ and 19.23, $ps < .0025$. The analysis of the female subjects also yielded quadratic and cubic seconds effects, $Fs(1, 9) = 8.29$ and 11.11, $ps < .025$, but there was a linear trials by cubic seconds interaction, $F(1, 9) = 5.76$, $p < .05$, not found for males. Thus the analyses indicated that both sexes show the significant orienting response to the onset of stimulus trains, but that the response of the females changes over trials. As is evident from figure 3, this interaction results from habituation occurring in female but not male subjects. Since there was no significant interaction of trials by sex for trials 1, 3, and 5, the different response development is unlikely to be due to changes in heart rate level for one sex or the other. Further analyses of each trial (see Appendix C) demonstrate that stimulus onset does not differ between males and females to the initial stimulus, but only

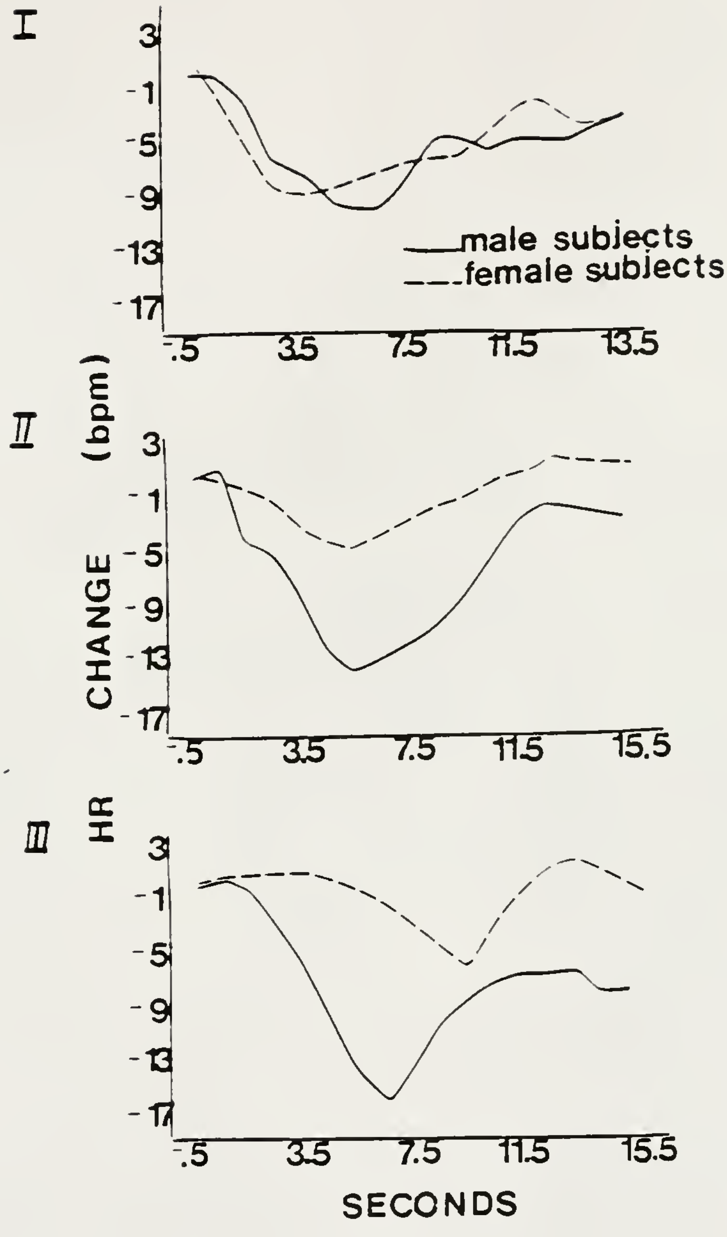

Figure 3. Response to stimulus onset trials 1 (subfigure I), 3 (subfigure II), and 5 (subfigure III) for male (solid line) as compared to female (borken line) subjects.

to trials 3 and 5, where the response of the females is significantly smaller than that of the males (see Figure 3). Therefore, these results cannot be explained as a sex difference in responding to pulsed auditory stimuli per se. Rather, they may indicate a faster learning of the temporal interval on the part of the females. There is a precedent in the literature for this possibility (Stamps and Porges, 1975), as will be described in the discussion section.

Stimulus Offset Trials 2 and 4

In contrast to the response to stimulus onsets, the response to stimulus offset trials looks rather erratic and is slightly accelerative (see Figure 2). An analysis of trials 2 and 4 yielded no significant effect for seconds by themselves, but only an interaction of linear seconds by sex by frequency, $F(1, 12) = 5.09$, $p < .05$, and a trials by cubic seconds by sex by frequency interaction, $F(1, 12) = 5.95$, $p < .05$. Follow-up analyses indicated these interactions reflected a significant cubic seconds effect, $F(1, 8) = 6.62$, $p < .05$ for the female subjects for trials 2 and 4 combined and a main effect for seconds, $F(16, 80) = 2.54$, $p < .05$, on trial 4 for only those male subjects who had been tested at 1600 Hz (see Figure 4). Taken together, the erratic significance pattern for trials 2 and 4 seems likely to result from chance events and not consistent with an orienting response to stimulus offset (e.g. Berg & Chan, 1972, Davies & Berg, 1983).

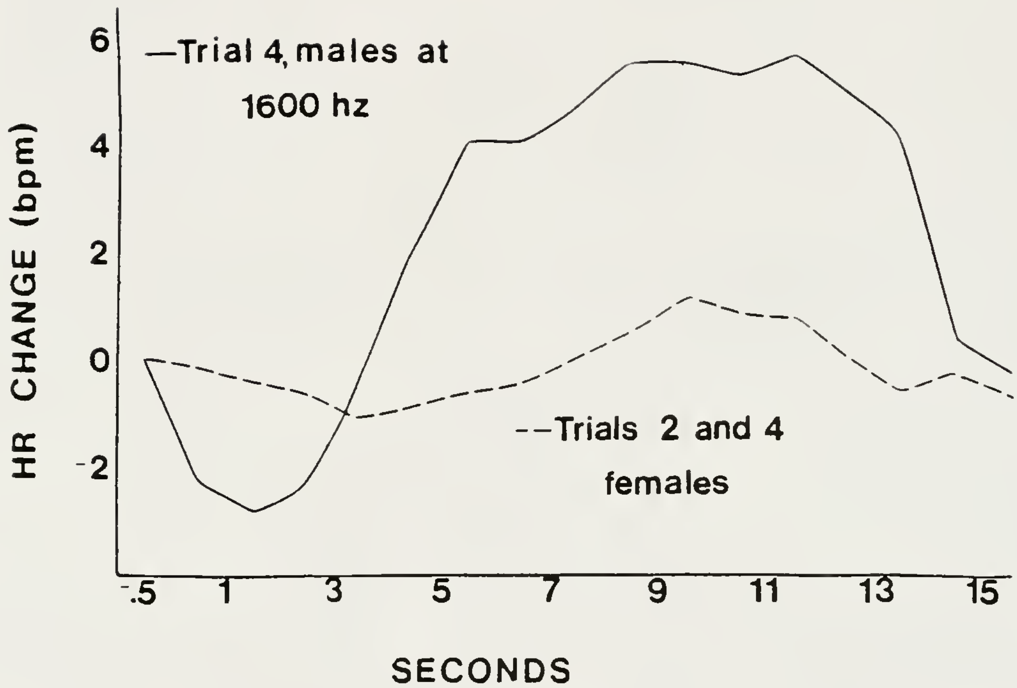

Figure 4. Response to stimulus offset: male subjects tested at 1600 Hz on trial 4 (solid line) and the averaged response for trials 2 and 4 for female subjects only (broken line).

Additional Offset Analyses and Comparisons

The offset following the 60 seconds of pulsed stimuli occurring during the initial test trial (see Figure 1) was analyzed, since the long uninterrupted train of pulses might have increased the chance for an offset response. However, no significant seconds effect was found. Nonetheless, inspection of this trial and the subsequent offset trials suggested analysis of a pooled block of trials might be more successful. Therefore, trials 8, 10, 12, and 14 were combined for an analysis. Only those 15 subjects who remained in a satisfactory state for all of these trials were used in the analysis with sex, frequency, trials and seconds as factors. The response to stimulus offset still did not reach significance. The analysis was repeated for trials 8, 10, 12 with the same result. For comparison with responding to stimulus onset, an analysis was conducted on stimulus onset trials 9, 11, and 13. The analysis indicated that there was no longer a significant response to tone onsets either, probably due to habituation, which may have been facilitated by the occurrence of 60 seconds worth of pulses during the test trials.

Based on the previous studies showing offset responses to continuous stimuli, the lack of an orienting response to stimulus offset for pulsed stimuli is unexpected. This finding as well as the surprisingly large orienting response to pulsed stimulus onset suggested the value of analyses to

directly compare the onset and offset responses to pulsed and continuous stimuli.

Pulsed versus Continuous Stimuli

From a very similar previous experiment (Davies & Berg, 1983), data were available on heart rate responses to stimulus onsets and stimulus offsets of continuous tones. A complete comparison of these data with the data from the present experiment is presented in Appendix D and summarized here.

The subjects previously tested with continuous stimuli were similar to those in the present study in most aspects. On the average they were one day older than the pulsed group. The timing and loudness of the stimuli was the same for trials in question. In contrast to the present study, parent(s) in the earlier study stayed with the infant throughout the experiment and neither the parents nor the experimenter listened to noise to mask the tones. However, interactions between the adults and the infants were minimized. Data for the group previously tested with continuous stimuli were available only for 8.5 poststimulus seconds, so the same analysis interval was employed for the present pulsed stimulus data. The 10 subjects from the pulsed group who were tested at 1000 Hz, the only frequency used in the earlier study, provided data for comparison.

A comparison of the onset and offset responding to the two stimulus types is shown in Figure 5. In contrast to the

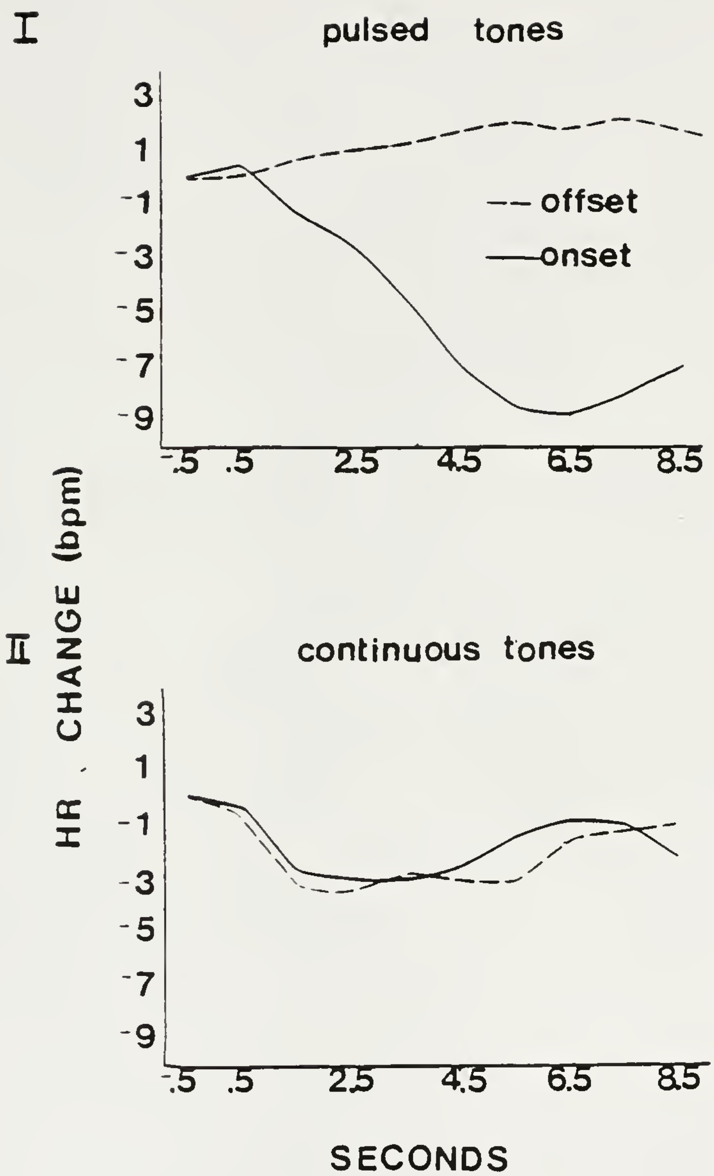

Figure 5. Responses to stimulus onset trials 3 and 5 (solid line) compared to stimulus offset trials 2 and 4 (broken line) for pulsed tones (subfigure I) and continuous tones (subfigure II).

previously shown differences in onset and offset responses to pulsed stimuli, the onset and offset responses for those subjects who listened to continuous tones appear very similar, namely a quadratic deceleration in both cases (see Figure 5). This contrast was confirmed in an analysis comparing offset trials 2 and 4 to onset trials 3 and 5 by a significant on/off by linear seconds by pulsed /continuous interaction, $F(1, 12) = 8.83$, $p < .025$.

To follow up on this result, the response to stimulus onset only was compared for pulsed versus continuous tones.[3] The fact that the response to pulsed stimuli is larger and more sustained than the response to continuous stimuli was substantiated by a significant linear seconds by pulse/continuous interaction, $F(1, 12) = 19.12$, $p < .001$. The interaction with linear seconds instead of quadratic seconds was to be expected, since with this shorter interval of 8.5 seconds the recovery period of the large orienting response to pulsed stimuli is cut off (see Figure 2).

Analysis of offset responding led to the opposite finding. While the offset of continuous tones results in an orienting response, the offset of pulsed tones is not accompanied by a clear response (Figure 5). Statistical

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[3] Only trials 3 and 5 were used for the analysis because for the continuous group the response to trial 1 may have been influenced by an insufficient baseline period.

evidence for this was a significant quadratic seconds by pulse/continuous interaction, $F(1, 12) = 6.29$, $p < .05$.

Finally, stimulus onset responses were compared to stimulus offset responses for the continuous group only. There was no significant on/off by seconds interaction. The response shape was a deceleration of quadratic order, $F(1, 8) = 15.19$, $p < .025$ (see Figure 5).

Response to Stimulus Omission, Trials 6,7 and 25,26

For trials 6 and 7 all 20 subjects were available. The analyses on trials 25 and 26 were initially done only on those 8 subjects who were in a satisfactory state on these and all previous trials throughout the experiment, but subsequently an attempt was made to replicate the obtained results with analyses involving all subjects who were in a satisfactory state on trials 25 and 26, regardless of prior interuptions of state.

Stimulus Omission Trials 6 and 7

The first omissions of a stimulus offset and subsequent onset (trials 6 and 7) were analyzed separately because the responses to stimulus onset and offset on trials 1 through 5 were markedly different. Also, the response to a first and a second stimulus omission may not necessarily be the same, and the response curves of these two trials look rather dissimilar.

By the beginning of trial 6 (Figure 6), the heart rate level had returned to 151.42 bpm, a value slightly above what it was at the beginning of trial 1. Thus, the response to an offset omission should not be influenced by an unrecovered orienting response. The response to offset omission (trial 6) is a heart rate deceleration that starts about two seconds after the omission, reaches its nadir at 9.5 seconds and is not completely recovered at the end of the 15.5 seconds interval (Figure 6). However, in an analysis that included age, sex, frequency, and seconds as factors, response effects became significant only in the interaction of sex by age with linear and quadratic seconds, $Fs(1, 12) = 4.91$ and 4.79, $ps < .05$, respectively.

Separate analyses for males and females, with age and seconds as factors, yielded significant results only for the females (see Figure 7): a linear seconds effect, $F(1, 8) = 12.13$, $p < .01$, and a linear seconds by age interaction, $F(1, 8) = 5.54$, $p < .05$. To follow up on these results, the older females and the younger females were analyzed separately with only seconds as a factor. There was a linear seconds effect, $F(1, 4) = 38.14$, $p < .005$, for the older females (see Figure 7), but analyses on the younger females yielded no significant results.

In summary, only a subgroup, the female subjects, gives a significant response to the omission of a stimulus offset. Even though the deceleration is larger for the

Figure 6. Response to the initial stimulus omissions: offset omission on trial 6 (first omission, solid line), and onset omission on trial 7 (second omission, broken line).

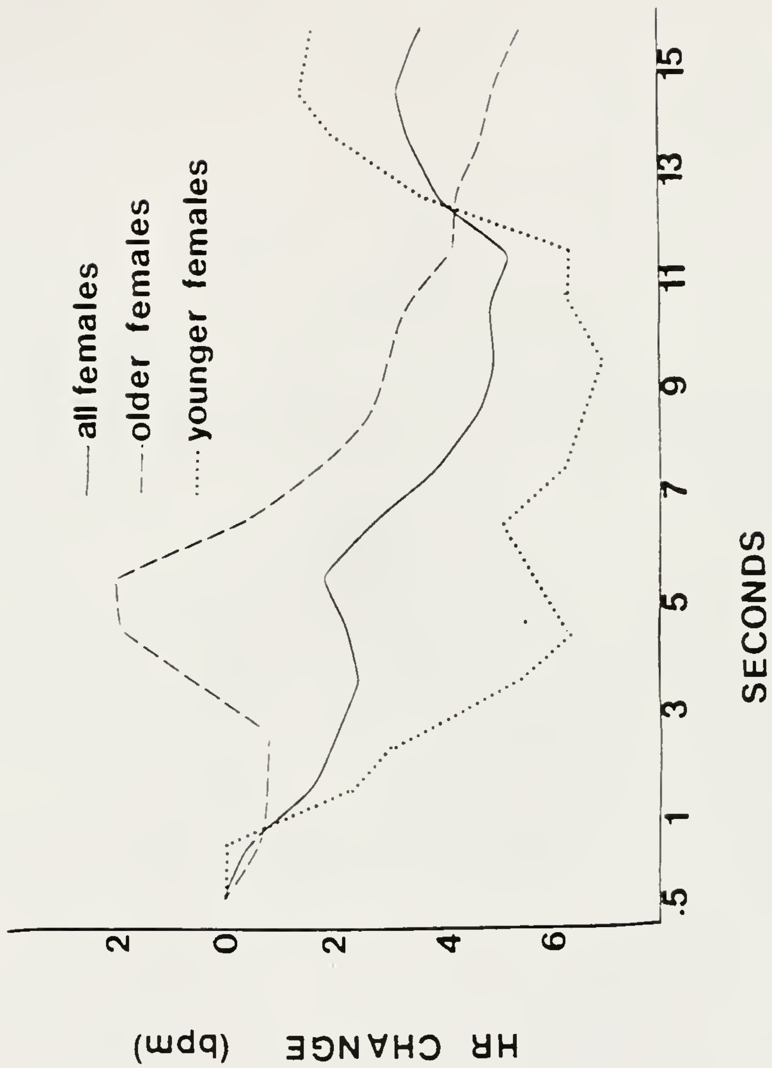

Figure 7. Response to stimulus offset omission trial 6 by all female subjects (solid line), by the older female subjects (broken line), and by the younger female subjects (dotted line).

younger females, it is more consistent and therefore becomes significant only for the older females. A high response variability typical for the age group of the younger subjects (Graham, Anthony, & Zeigler, in press).

The response to the onset omission, trial 7, looks rather irregular and is generally accelerative (see Figure 6). This acceleration may in part be due to an incomplete recovery of the heart rate deceleration on trial 6. An analysis of trial 7, including age, sex, frequency, and seconds as factors, yielded no significant results. Thus, subjects responded to only the first of two test trials, and this was restricted to a subgroup of female infants.

Stimulus Omission Trials 25 and 26

For trial 25, an onset omission, data of those 8 subjects who remained in a satisfactory state throughout the experiment were analyzed. The response is a brief acceleration over the first 3 seconds of the interval followed by a deceleration that does not recover over the entire 15.5 seconds (see Figure 8). The deceleratory part of the curve was expected from the literature (e.g. Clifton, 1974). The brief acceleration apparently does not result from an incomplete recovery of the response on the previous trial: the response to stimulus offset trial 24, like all the offset responses, was small, and already at 6.5 seconds before the onset of trial 25 the heart rate had slightly exceeded the final heart rate just prior to that offset.

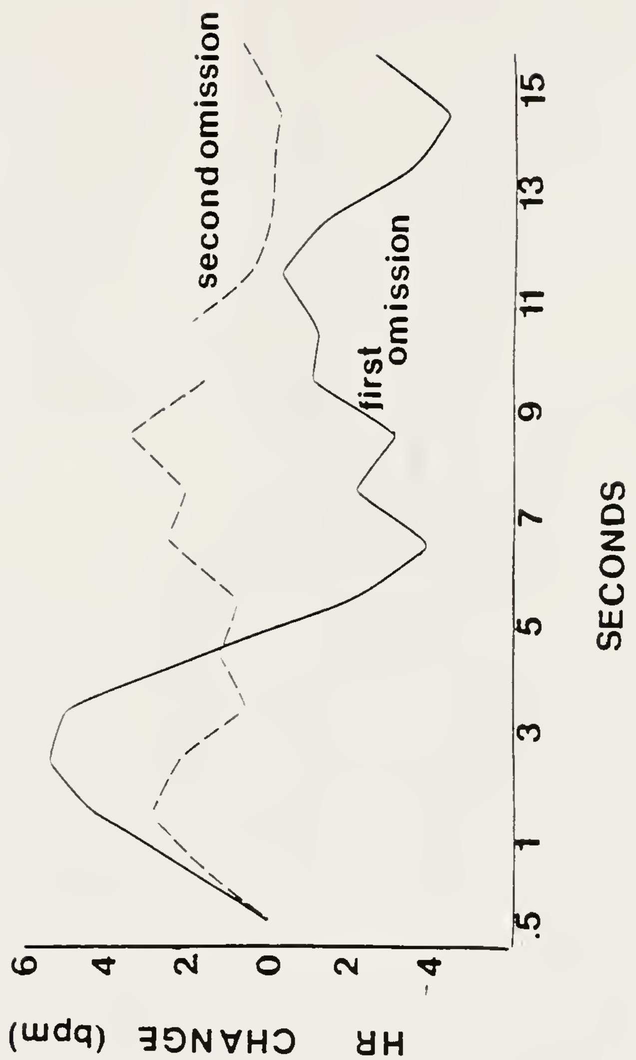

Figure 8. Response of eight subjects to the final stimulus omissions: onset omission on trial 25 (first omission, solid line), and offset omission on trial 26 (second omission, broken line).

Furthermore, the baseline value of trial 25 exceeds the baseline value of trial 24 by .54 bpm and is only slightly lower (.28 bpm) than that of trial 23. Even though there is no immediate explanation of the acceleratory part of the curve, accelerations smaller than the one on trial 25 had been observed on several trials throughout the experiment to precede the deceleratory response (see Figures 3, 6, 7, 9, and 10). In an analysis with sex and frequency as between subject factors and seconds as a within subjects factor, a significant effect for overall seconds, $F(16, 64) = 2.27$, $p < .05$ was found. Since there were no interactions with sex or frequency, the analysis was repeated without these two factors to provide some additional degrees of freedom. The second analysis revealed a significant linear seconds effect, $F(1, 7) = 6.62$, $p < .05$, in addition to the main effect of seconds.

When the analyses were repeated with the additional four subjects who had become fussy on previous trials, there were no significant effects. The analysis was again repeated with only seconds as a factor which again resulted in a linear seconds effect, $F(1, 11) = 6.28$, $p < .05$, and an effect for overall seconds, $F(16, 176) = 2.75$, $p < .025$.

The mostly accelerative response to the final stimulus offset omission (trial 26) appears rather irregular and does not indicate a definite response. The analysis of eight good subjects with sex, frequency, and seconds as factors

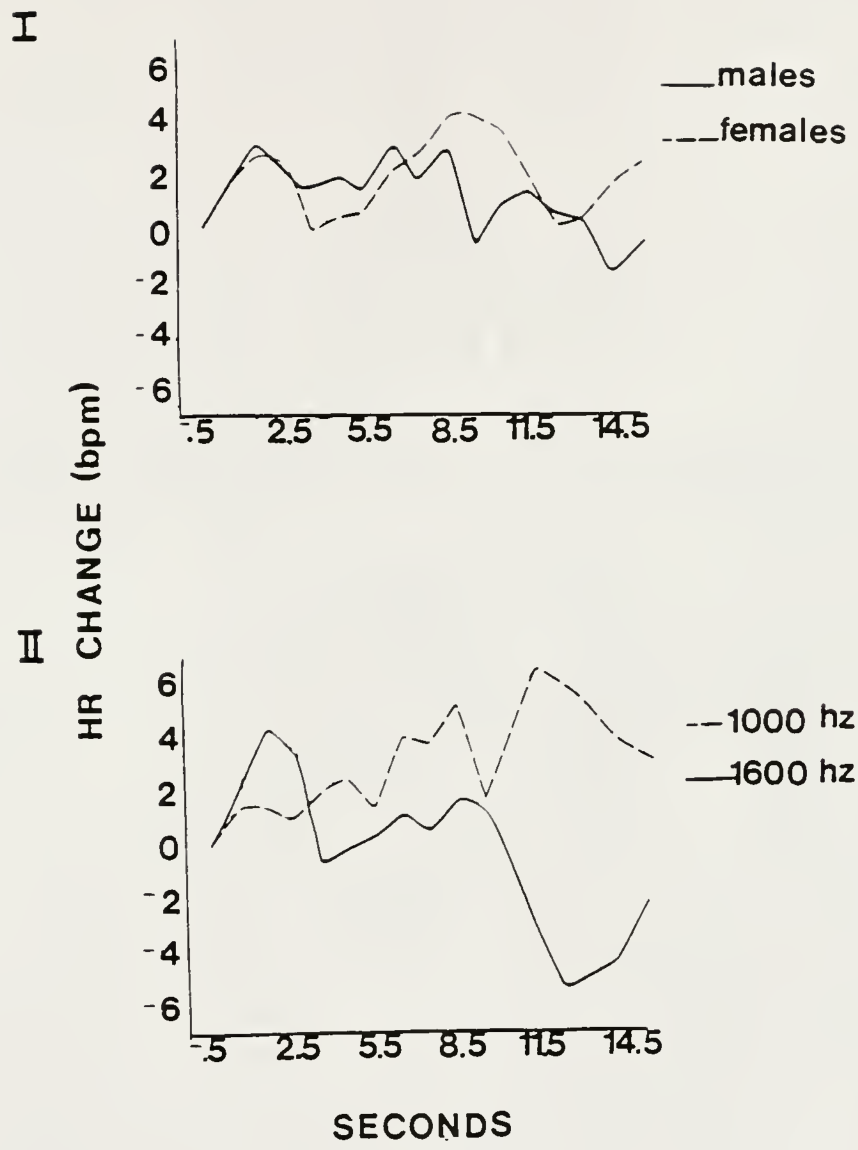

Figure 9. Response of eight subjects to offset omission trial 26 (second omission). Subfigure I: male subjects (solid line), and female subjects (broken line). Subfigure II: subjects who started the session at 1600 Hz (solid line), and subjects who started the session at 1000 Hz (broken line).

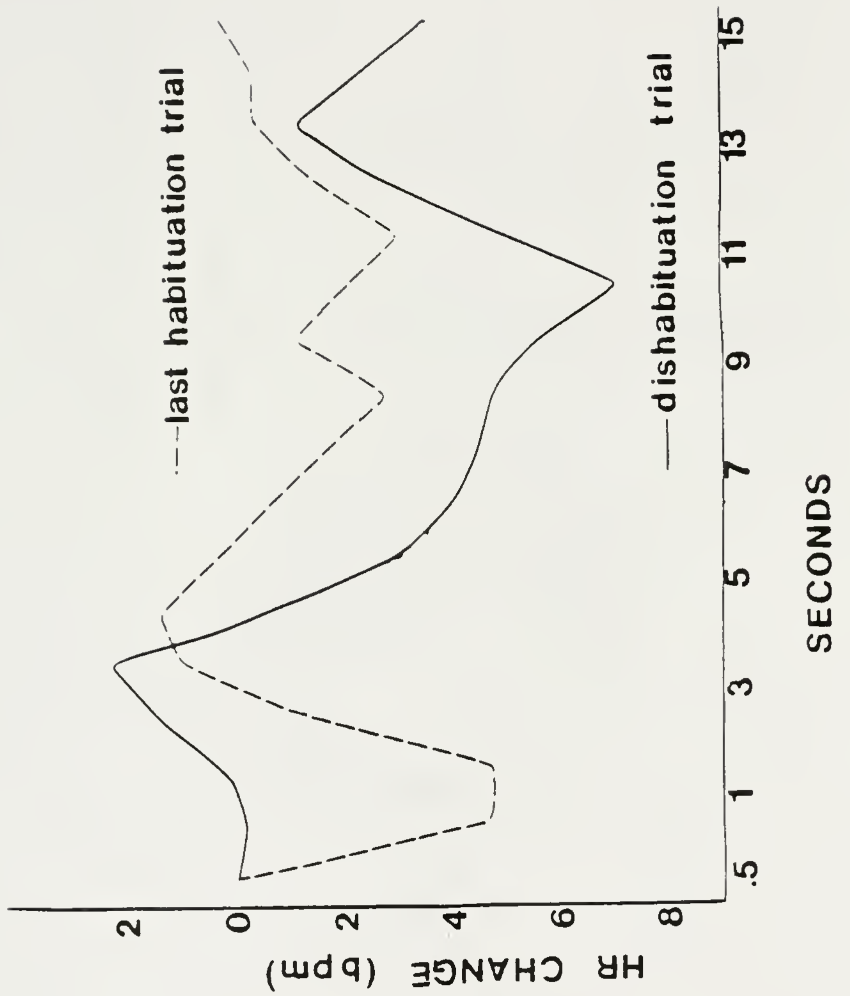

Figure 10. Response of eight subjects to the last habituation trial (trial 19, broken line), and the first dishabituation trial (trial 21, solid line).

showed a main effect for seconds, $F(16, 64) = 4.1$, $p < .00025$, a linear seconds by sex by frequency interaction, $F(1, 4) = 15.87$, $p < .025$, and a cubic seconds by sex by frequency interaction, $F(1, 4) = 20.90$, $p < .025$. When analyses were made for each frequency separately with sex as a between subjects factor, there was only an interaction of overall seconds by sex, $F(16,32) = 3.02$, $p < .005$ for those 4 subjects who started at 1000 Hz. For the subjects who started at 1600 Hz there was a linear seconds effect, $F(1,2) = 72.15$, $p < .025$ and a linear seconds by sex interaction, $F(1, 2) = 54.04$, $p < .025$. Since there are so few subjects, the sample will not be broken down further to examine interaction effects. While the heart rate curves for the subgroup of male subjects, female subjects, and subjects who started the session at 1000 Hz are mostly accelerative, the heart rate curve for those subjects who started at 1600 Hz consists of an acceleration with a subsequent deceleration (see Figure 9), similar to the overall response to trial 25. Next, an analysis of all 12 subjects who were in a good state on trial 26 was performed in order to confirm the above results. A linear seconds effect, $F(1, 8) = 8.10$, $p < .025$, an interaction of linear seconds by frequency, $F(1, 8) = 19.08$, $p < .0025$, $p < .005$, and a linear interaction of seconds by sex by frequency, $F(1, 8) = 17.23$, $p < .005$, was found. However, when subjects were examined for the two different frequencies separately with

only seconds included as a factor, there were no significant effects.

The slight heart rate acceleration over all subjects on trial 26 may in part be due to a recovery to baseline level after the deceleration of trial 25; at the onset of trial 26, the heart rate level is still 1.29 bpm below what it was at the beginning of trial 25. Only a subgroup, those subjects who started the session at 1600 Hz, showed a heart rate deceleration. It is perhaps relevant that this is the same subgroup who shows dishabituation in the trials just prior to these omission trials (described below).

To provide for a comparison with equivalent power and subject selection between the early and late tests of stimulus omission, trials 6 and 7 were analyzed with only those eight subjects who were used in the analyses of trials 25 and 26. There were no significant results for either trial, indicating that the deceleratory heart rate response to the first of two stimulus omissions is not a response specific to the subgroup of those eight subjects. The sex effect may not have become significant because of the small number of subjects.

In conclusion, the response to the test trials consists of a deceleration to stimulus absence for the first omission only, regardless of whether that omission is one of onset or offset. However, there are some important qualifications evident. In the case of the initial test trials, the

decelerative response occurs for only a subgroup of the subjects and for the final test trials, this deceleration starts after a 3 second delay. The linear accelerative response that became significant on trial 26 only if two grouping factors were included, seems to be in part a late recovery of the decelerative response on trial 25 (see Figure 8). Only a subgroup, those subjects who had started the session with 1600 Hz, show a heart rate deceleration to trial 26. Thus, while there is a response to omission of a pulsing stimulus, it is not as clear as it was with simpler stimuli (Davies & Berg, 1983).

Dishabituation

Response on trials 19, the stimulus onset trial preceding the change in frequency, and 21, where the frequency changed, were analyzed for those 8 subjects who remained in a satisfactory state throughout the experiment. Aside from a big initial deceleration, there is little evidence of a coherent heart rate curve on the final habituation trial (trial 19), consistent with the expectation of a habituated response, whereas the new stimulus frequency (trial 21) appears to produce an extended deceleration following a brief initial acceleration (see Figure 10). In an analysis of trials 19 and 21 including sex, frequency, trials, and seconds a significant trials by quadratic seconds by frequency interaction, $F(1, 4) = 19.74$, $p < .025$, was found, indicating that the occurrence of

dishabituation depends on frequency. Further analyses of the dishabituation trials are only summarized here and a detailed account is given in Appendix E.

Only those subjects who changed from 1600 to 1000 Hz showed statistical evidence of dishabituation. The frequency specificity of the dishabituation effect was found with eight subjects only, with all subjects who were in a satisfactory state on these trials, and in analyses including two stimulus onset trials from before as well as after the stimulus change (trials 17, 19, 21, and 23). An analysis of the stimulus onset trial preceding the frequency change (trial 19) indicated that the response to regular stimulus trials had habituated. The response to the frequency change trial (trial 21) again was frequency specific for eight as well as for all available subjects. However, only for those eight subjects who remained in a satisfactory state throughout the entire experiment, significant results were obtained on the dishabituation trial (trial 21), when the responses to both frequencies were analyzed separately. For both frequencies, the heart rate change is deceleratory. The response of those subjects who switched from 1600 to 1000 Hz strongly ressembles a typical orienting response: after a brief delay there is a deceleration followed by a return to baseline. The response to a change from 1000 to 1600 Hz, on the other hand, is a

more irregular deceleration which has not started to recover 15.5 seconds after stimulus onset (see Figure 11).

Anticipation

Since there is no positive evidence in the literature on the development of an anticipatory heart rate response in one to two-month-olds, decisions on what trials to analyze had to be based on logical inferences and on the appearance of the heart rate curves. Based on inspection of the data, there is generally very little evidence for anticipatory responding, though the last two prestimulus onset intervals before a frequency change (trials 19 and 21) appear most promising for a significant decelerative heart rate response (see Figure 12). These trials might have the greatest expectation of anticipatory responses since they are onset trials, where responding was previously greatest, and since these come at the end of the most extended series of uninterrupted regular stimulus trials.

An analysis of those eight subjects who remained in a satisfactory state throughout the experiment with sex, frequency, trials, and seconds included as factors yielded a cubic seconds effect, $F(1, 4) = 18.84$, $p < .025$. Since there was no interaction with sex or frequency, the analysis was repeated under omission of these factors, resulting in a quadratic seconds effect, $F(1, 7) = 7.28$, $p < .05$.

The next step was to assess the reliability of this anticipatory response by repeating the analysis with all 12

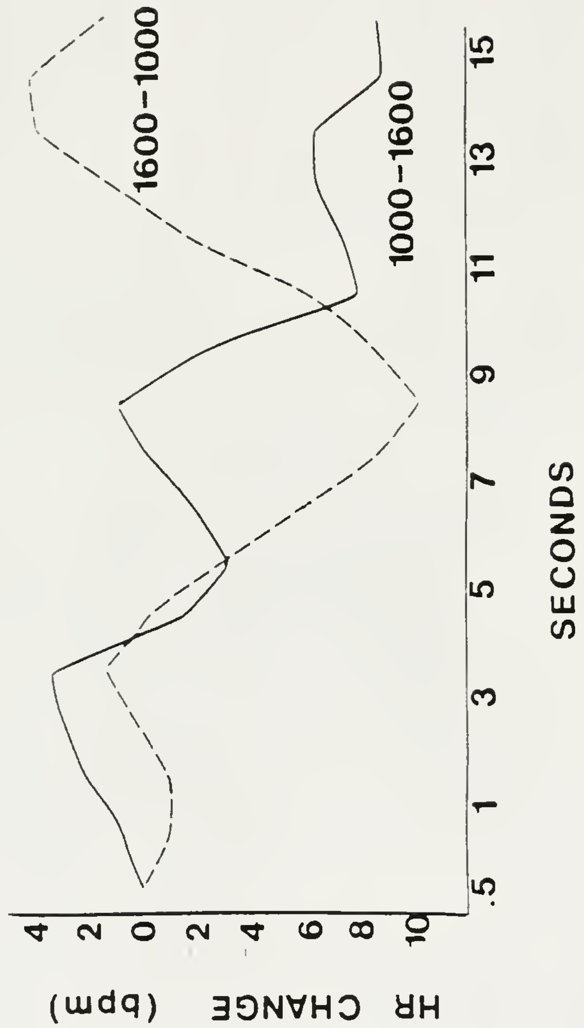

Figure 11. Response of eight subjects to the first dishabituation trial (trial 21). Four subjects who switched from 1000 to 1600 Hz (solid line) and four subjects who switched from 1600 Hz to 1000 Hz (broken line).

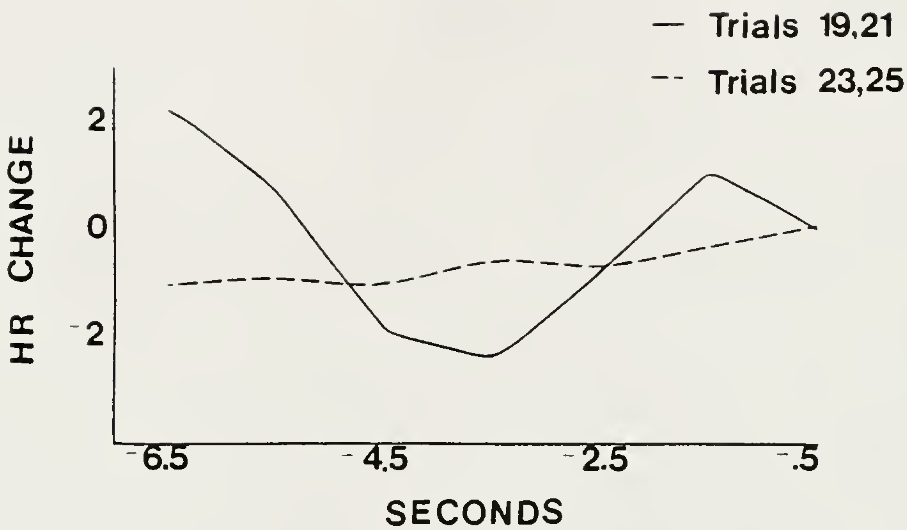

Figure 12. Anticipatory response of eight subjects to combined stimulus onset trials before the frequency change (combined trials 19 and 21, solid line) and after the frequency change (combined trials 23 and 25, broken line).

subjects who were in a satisfactory state on these particular trials. One of the 12 subjects had briefly become fussy during previous trials and three changed to an unsatisfactory state after these trials but before the end of the experiment. The analysis, including sex, frequency, trials, and seconds as factors yielded no effect for seconds per se, but only some interaction effects: a trials by linear seconds interaction, $F(1, 9) = 7.78$, $p < .025$, and a trials by linear seconds by sex by frequency interaction, $F(1, 9) = 7.07$, $p < .05$. Since these results were very different from the results obtained with only eight subjects and since they were also rather complex, they were not followed up on. Nevertheless, they indicated that the anticipatory response is rather weak and unreliable.

The Anticipatory Response after Stimulus Change

In order to test whether the anticipatory response is disturbed through the tone change, as figure 12 suggests, an analysis was done comparing the anticipatory response to trials 19 and 21 (block 1) with the anticipatory response to trials 23 and 25 (block 2). Sex, frequency, blocks, trials, and seconds were factors in the analysis with eight subjects. A significant blocks by cubic seconds interaction, $F(1, 4) = 10.84$, $p < .05$ indicated that the anticipatory response is indeed influenced by the change in frequency. An analysis of trials 23 and 25 with sex, frequency, trials, and seconds as factors yielded a

significant cubic seconds effect only in interaction with sex, $F(1, 4) = 12.67$, $p < .025$. When trials 23 and 25 were examined for both sexes separately with frequency, trials, and seconds as factors, no significant seconds effect emerged. Thus, the anticipatory response seems to be disturbed by the change in tone frequency. The analysis comparing the anticipatory response before and after stimulus change was not repeated with all available subjects, since they did not show a significant response on trials 19 and 21.

In conclusion, the anticipatory response seems to be weak under the present experimental conditions, and what little there is of an anticipatory response is disturbed by the dishabituation trials. This makes the significant time-locked response on trial 25 to stimulus omission even more impressive. It confirms previous research that at this early age a time-locked response is easier to elicit than an anticipatory response (Haith, Hazan, & Goodman, 1984, Davies & Berg, 1983).

CHAPTER IV

DISCUSSION

To summarize the results, analyses indicated that there was a large orienting response to the onset of the regular pulse trains but no consistent response to their offset. This is different from the outcome for continuous stimuli, where there is a small orienting response to stimulus onset as well as to stimulus offset. The response to stimulus omission was less clear than it had been with continuous tones in Davies and Berg (1983). With the exception of a subgroup on the very last stimulus omission trial, significant responses were found only for the first of each pair of stimulus omission trials; for the initial pair this was true only for the female subjects. Thus, for response to regular trials the critical factor determining responding is whether it is stimulus onset or stimulus offset, whereas for the omission response it seems more important whether it is a first or a second omission. With regard to dishabituation, even though the changed stimulus elicited a significant response for both frequencies, this response was significantly larger than that occurring prior to the change only for those subjects who had switched from 1600 to 1000

Hz. Anticipatory responding was weak and it appeared to be disrupted by the change in frequency.

Analyses of the regular stimulus onset trials (trials 1, 3 and 5) showed a deceleratory quadratic orienting response which was larger than would be expected for this age group based on research with continuous stimuli. A comparison with data from a similar previous experiment (Davies & Berg, 1983) yielded results consistent with Graham et al. (in press), namely that in young infants pulsed stimuli elicit larger orienting than continuous stimuli. Graham et al. hypothesized that the reduced response to the continuous stimulus, with its single onset and offset, may relate to immature processing of transients by young infants. The transient system is hypothesized to initiate and/or facitate the attentional processing necessary for an orienting response to occur. Since pulsed stimuli contain a series of onsets, the infant`s deficient transient system becomes activated over and over and therefore an orienting response is facilitated.

In contrast to the large onset response, there was no reliable response to stimulus offset to the regular 20 second stimulus trials or even after the 60 second pulse train (trial 8). The question arises as to why a stimulus that elicits a comparatively large orienting response and thus by implication elicits a large degree of attention does not attract interest at its offset. Based on Sokolov's

(1960) concepts, an orienting response is expected as a result of change of any sort and therefore should occur to stimulus offset as well as to stimulus onset. Work by Berg and Chan (1972) with adults supported the notion that with continuous stimuli at least, offsets elicit responses equivalent to those at onset.[4] For a similar previous experiment (Davies & Berg, 1983) using continuous tones responses to onset and offset were statistically the same for one to two month olds, and for seven-month-olds offset responses were only slightly smaller than onset responses. For pulsed tones, however, a statistically unequivocal orienting response has been reported only by Leavitt et al. (1976), while there have been several reports of either no response (e g. Clifton & Meyers, 1969) or only a weak response (Berg, 1974).

There are several possibilities to explain the reduced chance of offset responding for pulsed stimuli. The prediction of Bohlin et al. (1981) that an offset response would occur if the pulse train was only long enough was not supported by the present experiment. According to the present experiment, the lack of an offset response is not

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[4] There have been instances in the literature (e. g. Bohlin et al., 1981) when offset responses were smaller than onset responses or even nonexistent. These have occurred when conditions preceding offset were less favorable than those preceding onset. Few studies have tested offset and onset responses under truly comparable conditions.

due to the fact that pulsed stimuli provide less total stimulation than continuous stimuli, since there was still no offset response after a 60 second pulse train. With the 50 percent duty cycle employed, this stimulus included a total of 30 seconds of tone stimulation, more than sufficient for an offset response to a continuous tone.

Another possible hypothesis is that differential habituation may take place for onset and offset responses. During a pulse train, the subject is exposed to a stimulus offset after every pulse and therefore may have habituated to offsets before the train stoped. Based on this hypothesis, the longer the pulse train, the smaller would be the probability of an offset response. At pulse train onset, on the other hand, the subject hears the first onset after 20 seconds of no stimulus. This view implies that a pulse train is not (or only in a very limited way) perceived as a gestalt. Developmental research indicates that in fact gestalt perception is deficient in young infants (Bertenthal, Campos, & Haith, 1980). An implication of this view is that offset responses to pulsed stimulation might be easier to elicit in older infants or adults, when gestalt perception has matured.

Finally, there is the possibility that the lack of offset response may be related to the pulse rate. Pulse rates that closely match the frequency of rhythms that are exhibited naturally by the infant may be processed

differently from other stimuli. In Berg's (1972) study where pulses came on for 400 msecs and stayed off for 600 msecs and thus produced two slightly different time intervals, none of which was a simple divisor of one second, the offset response was not statistically different for pulsed and continuous tones within the same analysis. However, there was not a substantial overall response to the offset of the 10 second stimuli employed.

The question remains why Leavitt et al. (1976) found an offset response with their 60 second train of speech stimuli. There is the possibility that the decelerative response constituted a recovery from the extended accelerative response to the speech stimuli. On the other hand, it could be that due to the high complexity level of speech stimuli the information difference between stimulus train and no stimulus train was heightened. Such an interpretation would be consistent with Sokolov (1960) since a larger change in information should heighten the chance for a significant orienting response.

The response to stimulus omission was less clear than it had been in a previous experiment using continuous stimuli (Davies & Berg, 1983). The predominance of a response to the first omission is similar to Clifton's (1974) results, where there was a large decelerative response only to the initial stimulus omission. In contrast, Davies and Berg (1983) found a decelerative

response to both consecutive omission trials. Not only does the time-locked response (the response that occurs at the omission of the event instead of in its anticipation) seem less robust with pulsed than with continuous tones, but the response curve itself also appears more irregular. The explanation for this difference may lie in the attention-getting power of the stimuli employed. Clifton (1974) as well as the present study used stimuli that strongly attract attention and likely demand more information processing than the continuous tones used by Davies and Berg (1983): glucose presentations and pulsed pure tones, respectively. This is consistent with Thomas and Weaver's (1975) theory that with more complex stimuli timing becomes worse since attention is drawn away from the timing mechanism by the complex stimulus. Their theory assumes that attention is shared between an f processor and a g processor. The f processor is the "timer" counting subjective pulses and the g processor is an (in their experiment visual) information processor. As the g processor captures more attention, the output of the f processor becomes less reliable, resulting in higher variability of the subject's timing performance. Thomas and Weaver formulated and tested their theory only with brief visual stimuli (in the 1 second range), so this study extends their finding to a larger set of stimuli. The findings of the present study are also in agreement with

Brackbill et al. (1967), where infants rapidly acquired simple temporal intervals but were impossible to condition to a more complex temporal sequence. The Thomas and Weaver hypothesis could also explain why the precise timing in infants found by Brackbill et al. (1967) and Davies and Berg (1983) is not more apparent in everyday life where situations usually are rather complex.

In the present experiment, the females exhibited better timing than the males, because only the females showed a time-locked heart rate deceleration to the first stimulus omission. They also showed evidence of habituation over the first three stimulus onset trials. The orienting response to the first stimulus was the same for both sexes, while for the two following stimulus onset trials, the response became significantly smaller for the females, which may indicate a faster learning of the temporal interval as compared to the males. With auditory stimuli sex effects on the orienting response per se are unusual, while sex effects for timing have been reported previously for anticipatory heart rate responding (Stamps & Porges, 1975), though this was not unequivocally replicated in a later study (Stamps, 1977).

In summary, there is weak evidence that females may be somewhat better at timing than males: there is an unreplicated advantage of female newborns at anticipatory responding (Stamps & Porges, 1975), and an advantage of female two-month-olds for the time-locked but not the

anticipatory response (present experiment) that was not replicated in the latter part of the study. The combined evidence may point to a somewhat better general timing ability in females than in males; however, to date evidence is too sparse to make conclusions on the parameters necessary to reliably demonstrate the effect.

Only those subjects who switched from 1600 to 1000 Hz, showed clear statistical evidence of dishabituation. The differential dishabituation for the two frequency groups was unexpected, since the two frequencies employed span a rather narrow range. The frequency specific response could be due to a peculiarity of those subjects tested at that frequency, such as that they remained somewhat more alert in the latter part of the experiment.

Another possiblility is that the frequency effect is real. In a study with newborns by Brown, LeVita, Kush, and Rothstein (cited by Graham et al., in press) using frequency modulated tones centered at 1200 Hz and 2000 Hz the significant response to frequency change was mainly the result of the shift from the high to the low frequencies. Along the same lines, lower frequencies have been shown to be preferred by young infants (Berg & Berg, 1979).

A search of the literature revealed only one other study that found heart rate dishabituation to auditory stimuli with infants comparable in age to those in the present study: Leavitt et al. (1976) used with 6-week-olds

a change of tone frequency from 1100 to 1900 Hz in a no-delay paradigm; i.e., there were no intertrial intervals between the pulse trains in order to minimize the memory demands and thereby maximize the possibility of heart rate dishabituation to a change in tone frequency. The dishabituation effect of Leavitt et al. was not frequency specific. The reason for this may have been that the infants of Leavitt et al. had an easier task than the infants in the present experiment: they had a larger frequency change and a no-delay paradigm. The infants in the present study may have been tested with a frequency change that was closer to the threshold value for heart rate dishabituation, since the dishabituation effect over trials became significant only for the frequency change from high to low. Thus a frequency preference that may have been eliminated by a ceiling effect in Leavitt et al. could have become apparent in the present study.

Statistical evidence for an anticipatory response was very weak. Only through averaging trials could a significant change in heart rate be obtained. The shape of the anticipatory activity that developed, even though deceleratory, was dissimilar to the shape typical for adult subjects (see, e.g., Johnson & May, 1969) in that it reached its lowest point before the onset of the event in question. This may indicate temporal inaccuracy. The fact that in Brooks and Berg's (1979) and in Davies and Berg's

(1983) experiments anticipatory responses developed in infants four-month-old and older under rather demanding temporal conditions while the two-month olds in the present experiment give only a weak response to a more optimal condition suggests a strong developmental change early in infancy.

The weak anticipatory effect in the present study was also subject to disruption by the change in tone frequency, a change that was perhaps distracting. Unlike the dishabituation effect, the disruption of the anticipatory response was not frequency specific. This disruption is consistent with the hypothesis that heightened complexity interferes with timing capability: The change in frequency makes the cognitive input more complex and therefore attention may be taken away from the "timer" (Thomas & Weaver, 1975), resulting in a disruption of the timing response. Perhaps the integrity of timing responses could provide a sensitive indication of stimulus discrimination. Disruption of a timing response following a shift from one stimulus to another would indicate that the two stimuli were distinguished. Of course, the exact parameters necessary to strengthen the anticipatory response sufficiently to make it statistically unequivocal and thus useful for stimulus discrimination experiments--possibly a series of continuous tones without stimulus omission trials--need to be ascertained through future experiments.

The present study confirmed, as previous studies had shown, that in young infants the anticipatory response is harder to elicit than the time-locked response (Davies & Berg, 1983; Haith, Hazan, & Goodman, 1984; Clifton, 1974): While on the stimulus omission trials ending the series (trials 25 and 26) the infants were responding to stimulus omission, the anticipatory response to trials 23 and 25 was nonsignificant. Statistical significance in this case, however, is no absolute measure of the prevalence of a certain response type, since the two responses are qualitatively different.

In conclusion, the present study found that pulsed stimuli elicit a large orienting response in one-to-two-month olds. Possibly, the multiple onsets inherent in a pulse train facilitate the orienting response or perhaps a stimulus that matches rhythms naturally occurring in the infant is easier to process. The absence of a reliable offset response to pulsed tones cannot be easily explained by an energy summation concept, since even after a 60 second pulse train there was no significant offset response. In contrast to the large orienting response that the pulsed stimuli elicited, the heart rate responses to stimulus omission were small and of irregular shape. This outcome is clearly different from what was reported for continuous tones (Davies & Berg, 1983), where the response to stimulus omission was not statistically different from

the response to the regular stimulus trials. These findings are in agreement with Thomas and Weaver's (1975) theory that when attention is shifted to information processing, timing becomes more variable. Furthermore, the present study confirmed that in young infants a significant time-locked response is more likely to occur than a significant anticipatory response (Haith, Hazan, & Goodman, 1984, Davies & Berg, 1983). The small and irregular anticipatory response that occurred in the present experiment was disrupted by a change in tone frequency. Unlike the dishabituation effect during stimulus on time that became significant only for the switch from a higher to a lower frequency, the disruption of the anticipatory response was not frequency specific.

APPENDIX A

INFORMED CONSENT

The purpose of this experiment is to investigate what sounds infants can hear and how well they pay attention to the sounds. Your child will be listening to a series of tones and speech sounds presented at various intervals. Your child's responses will help us to better understand what young infants listen to and like to hear.

We will measure heart rate by placing three sensors on your child, two on his chest and one at the bottom of his rib cage. Respiration will also be measured by taping to the infant's stomach a devise similar to a rubber band. The experiment usually will be completed in less than an hour.

Neither the sounds nor the response measures will cause any harm or discomfort to your child. We will carry out the experiment only after you have given us your written permission. Even after you sign this informed consent, you may withdraw your child from the experiment at any time. We will be happy to discuss your infant's responses with you. All information gathered here is confidential within legal limits. If you have any questions at any time during the session, we will be happy to answer them. You will be paid $5.00 for your participation, whether your baby completes the session or not.

I have read and I understand the procedure described above. I agree to allow my child ______________________ to participate in the procedure, and I have received a copy of this description.

____ ____________________
Parent's name Date

____ ____________________
Witness Date

Margarete Davies
303-2 Diamond Village
Gainesville, FL 32603

W. Keith Berg
2902 S. W. 1st Way
Gainesville, FL 32601

APPENDIX B

MEDICAL QUESTIONNAIRE

The data which we collect from your baby can be affected by a number of factors. The more information we have about your baby, the easier it will be to interpret these data. The following questions are for our use in better understanding your baby's responses, and no individual information will be reported. If you do not wish to answer any question, just leave it blank. Please feel free to ask us to clarify any of the questions.

Today's date________

Mother's name____ Mother's Age__________

Infant's name___________________________________ Infant's Birthdate__________

1. Has the baby had any recent colds, ear infections, respiratory difficulties, or any major health problems? If so, please specify, and provide the approximate dates and durations.

2. Is the baby now taking any medication? If so, what is it, how often and in what dosage is it taken, and what problem is it treating?

3. How many brothers and sisters does the baby have, and what are their ages?

4. If known, was the baby born early, late, or on time?

5. If known, what sort of medication did the mother receive during labor and during birth? If you do not know exactly, please indicate if there were any pills, injections, or gas received.

6. Were there any special problems during pregnancy, such as illnesses, infections, or injuries?

7. Were there any special conditions during birth, such as breech birth, Cesarean section, or use of forceps?

8. Was the Lamaze method used?

9. Where was the baby born?

10. Did the baby have to stay in the hospital for any extra period of time? If so, why?

11. Do you breast-feed your baby?

12. If so, are you taking any medication? If so, what is it, how often and in what dosage is it taken, and what problem is it treating?

THANK YOU FOR YOUR HELP!

APPENDIX C

RESPONSE DEVELOPMENT OVER THE BEGINNING STIMULUS ONSET TRIALS (1, 3, AND 5), MALES COMPARED TO FEMALES

In order to more accurately describe the females' change in response over trials and based on the significant trials by seconds by sex by frequency interaction reported in the previous section, trials 1, 3, and 5 were analyzed separately with only sex, frequency, and seconds included as factors. There was no difference in response between the groups for the first trial. A significant quadratic seconds effect, $F(1, 16) = 12.74$, $p < .005$, and a significant cubic seconds effect, $F(1, 18) = 6.91$, $p < .025$ indicated the expected orienting response to the first stimulus onset. For trial 3, there was again evidence for an orienting response in form of a quadratic seconds effect, $F(1, 16) = 20.00$, $p < .0005$ and a cubic seconds effect, $F(1, 16) = 10.83$, $p < .005$. In addition, there was a significant interaction of quadratic seconds by sex, $F(1, 16) = 5.42$, $p < .05$, suggesting a different response in males and females. An analysis of trial 5 again yielded evidence of an orienting response with a significant quadratic seconds effect, $F(1, 16) = 11.94$, $p < .005$. Again, there was an interaction with sex, this time by cubic seconds, $F(1, 16) = 7.79$, $p < .025$. Thus the orienting response to stimulus onset does not differ for the first trial but merely develops differently over trials.

APPENDIX D

PULSED VERSUS CONTINUOUS STIMULI

There were some minor methodological differences for the subjects that were tested with continuous stimuli. The mean age of the subjects was 67 days, compared to 68 days for the pulsed group. The subjects in the continuous group were not tested in a sound attenuating chamber but in an ordinary laboratory room with a background noise level of 35 dB (as compared to 22 dB in the sound attenuated chamber). While for the pulsed group a 60 second baseline interval preceded the onset of the first stimulus, the baseline interval for the continuous group was only about 10 to 20 seconds. Therefore trial number one was not used in any of the analyses. For the continuous subjects, the mother and the experimenter stayed with the infant throughout the experiment, and neither one listened to noise to mask the tones. The adults were kept out of the direct line of vision of the infant. The parents were instructed not to interact with the infant in any way. Fluorescent ceiling lights and occasional presentation of a quiet toy by the experimenter if the infant became restless helped the infants to maintain a quiet alert state. As with the pulsed group, data from infants in an unsatisfactory state were not used.

Since for the group that was tested with continuous stimuli data were available only up to 8.5 poststimulus

seconds, the same interval had to be used for the group that was tested with pulsed stimuli. Since for the pulsed group the response shows hardly any recovery over this time period (see Figure 5), a linear trend is expected to be characteristic for this group's orienting response. Because the 10 subjects that were tested with continuous stimuli all were tested with 1000 Hz, only those 10 subjects from the pulsed group were used who had also been tested at 1000 Hz.

Onsets Compared to Offsets, Trials 3 and 5 versus Trial 2 and 4

In the first analysis, age, sex, and pulse rate were included as between subjects factors and blocks (onset versus offset), trials, and seconds were included as as within subject factors. A significant on/off by linear seconds by pulse/continuous interaction, $\underline{F}(1, 12) = 8.83$, $\underline{p} < .025$ indicated that onsets and offset do not relate to each other in the same way for pulsed and continuous stimuli (see Figure 5). This result confirmed the visual impression from the heart rate curves that for continuous tones the response to onset and offset is very similar while for pulsed tones there is a large orienting response to stimulus onset and no response to speak of for stimulus offset. Thus a separate analysis of onset and offset trials became necessary. There was also a significant on/off by quadratic seconds by sex interaction, $\underline{F}(1, 12) = 5.37$, $\underline{p} < .05$, which

is impossible to interpret before more analyses have been made.

Stimulus onset trials 3 and 5. For the continuous group, the first trial was not included in the analyses, since the response may have been influenced by an insufficient baseline period. An analysis including age, sex, pulsing, trials, and seconds as factors yielded a significant linear seconds by pulsed/continuous interaction, $F(1, 12) = 19.12$, $p < .001$, indicating that the response to stimulus onset is different for pulsed and continuous stimuli for this age group (see Figures 2 and 5). Furthermore, the analysis yielded a main effect for seconds, $F(9, 108) = 2.8$, $p < .025$, which generally signifies a response to the stimulus, and a linear seconds by sex interaction, $F(1, 12) = 5.73$, $p < .05$, which needed further analyses to be interpretable.

Stimulus offset trials 2 and 4. An analysis of trials 2 and 4 including age, sex, pulsing, trials, and seconds as factors was conducted to assess whether the response to stimulus offset was different for pulsed and continuous stimuli as well. A significant quadratic seconds by pulse/continuous interaction, the only significant result in this analysis, $F(1, 12) = 6.29$, $p < .05$, indicated that this was the case: The orienting response to the offset of continuous tones stands in contrast to essentially no response to the offset to a pulse train (see Figure 5).

Since pulsed and continuous stimulation produce different onset as well as different offset responses, a comparison of onset and offset response of the continuous group only could be valuable.

Onset versus offset response to continuous stimuli. Trials 3 and 5 were combined into a block of onset trials and trials 2 and 4 were combined into a block of offset trials. Since sex was the only between subject factor that had yielded significant results in the previous analyses, it was the only between subjects factor maintained in this one. Within subjects factors were blocks, trials, and seconds. There was no significant blocks by seconds interaction with $F < 1$ for the blocks by quadratic seconds interaction as well as for the main interaction of blocks by seconds, indicating that onset and offset responses do not significantly differ for continuous stimuli. A significant quadratic seconds effect, $F(1, 8) = 15.19$, $p < .025$ signified the expected orienting response (see Figure 5). Thus, for continuous tones, the response to stimulus onset is the same as the response to stimulus offset, namely a heart rate deceleration of quadratic order, the typical orienting response.

To follow up on the sex effect found for stimulus onset trials 3 and 5 for the pulsed and continuous group combined, trials 3 and 5 were analyzed for the continuous group only with sex, trials, and seconds as factors. No interaction of

sex with trials or seconds was found. Thus, the sex effect seems to be limited to the pulsed group. Therefore, the analysis comparing stimulus onsets to stimulus offsets for the continuous group only was repeated under omission of sex as a factor in order to maximize the degrees of freedom and thus the chance to find a blocks by seconds interaction. Again, no blocks by seconds interaction was found, reaffirming the finding that for continuous tones the response is the same for stimulus onset and stimulus offset.

APPENDIX E

DISHABITUATION

A significant trials by quadratic seconds by frequency interaction had been found for the trial of frequency change (trial 21) and the previous stimulus onset trial (trial 19).Therefore, trials 19 and 21 were analyzed for each frequency separately with only trials and seconds as factors. Only those subjects who had changed from 1600 Hz to 1000 Hz showed evidence of dishabituation in form of a significant trials by quadratic seconds interaction, $F(1, 3) = 19.29$, $p < .025$. The response of these subjects to trial 21 strongly resembles an orienting response, whereas the response of those subjects who switched from 1600 to 1000 Hz is more irregular even though it is still deceleratory, as would be expected for an orienting response (see Figure 11). Since the first analysis had yielded an interaction effect with trials, single trial analyses were done to better describe the change in response. An analysis of trial 19 with sex, frequency, and seconds as factors yielded no significant results. This can be interpreted as habituation of the heart rate response to the pulsed stimuli, as had already been shown with the analysis on trials 9, 11, and 13. The analysis of trial 21 with sex, frequency, and seconds as factors showed a linear seconds effect, $F(1, 4) = 16.16$, $p < .025$, a linear seconds by frequency interaction, $F(1, 4) = 18.32$, $p < .025$, and a

cubic seconds effect, $F(1, 4) = 7.92$, $p < .05$. Thus, while there was no significant response to trial 19, there was a significant response to trial 21, which differed somewhat depending on frequency. To follow up on the seconds by frequency interaction, trial 21 was analyzed for each frequency separately (see Figure 11) with only seconds included as a within subjects factor. Those subjects who had switched from 1000 Hz to 1600 Hz showed a linear seconds effect, $F(1, 3) = 15.94$, whereas for those subjects who had switched from 1600 to 1000 Hz there was a significant effect for overall seconds, $F(16, 48) = 4.66$, $p < .025$. Thus, there is a significant response to trial 21 with both frequencies, even though the response shape differs somewhat. While subjects who started with 1000 Hz show a rather gradual and irregular deceleration that does not even start to recover over the 15.5 second interval, subjects who started with 1600 Hz show a response curve that except for a brief initial acceleration closely ressembles a typical orienting response: a deceleration and a subsequent recovery (see Figure 11).

In summary, for the eight subjects analyzed, the dishabituation effect is frequency dependent: in a comparison over trials it becomes significant only for those subjects who changed from 1600 Hz to 1000 Hz. While there is no significant response to trial 19, there is a significant response to trial 21 for both frequencies, even

though the shape of the response differs somewhat depending on frequency.

In order to confirm these results, the analyses were repeated with all 11 subjects who were in a satisfactory state on trials 19 and 21. Each of the subjects was in a satisfactory state up to and including trial 21, but three had a state change before the end of the session. The analysis of trials 19 and 21 with sex, frequency, trials, and seconds included as factors yielded a significant trials by linear seconds by frequency interaction, $\underline{F}(1, 7) = 6.21$, $\underline{p} < .05$, a significant trials by quadratic seconds by frequency interaction, $\underline{F}(1, 7) = 8.27$, $\underline{p} < .025$, and a significant trials by quadratic seconds by sex by frequency interaction, $\underline{F}(1, 7) = 6.85$, $\underline{p} < .05$. Thus, it was reaffirmed that the phenomenon of dishabituation was frequency dependent. However, when trials 19 and 21 were compared for each frequency separately, there were no significant results. Next, trials 19 and 21 were analyzed separately with sex, frequency, and seconds included as factors. Similar to the responses of the eight subjects only, there was no significant response on trial 19 and a significant interaction of overall seconds by frequency, $\underline{F}(16, 112) = 3.08$, $\underline{p} < .05$, on trial 21. However, when trial 21 was examined for each frequency separately, no significant results for either subgroup emerged. Thus, even though the results with all subjects

included pointed in the same direction as results with only eight subjects, they were not as clear cut. The reason for this may be that the additional subjects were briefly before a state change, which may have made heart rate responses more variable.

In order to gain additional evidence on the change in response and its frequency specificity, the two trials preceding the stimulus change, trials 17 and 19, and the two trials following the change, trials 21 and 23, were combined into two trial blocks. An analysis including sex, frequency, blocks, trials, and seconds as factors yielded a blocks by cubic seconds by frequency interaction, $\underline{F}(1, 4) = 20.65$, $\underline{p} < .025$, when only eight subjects were examined, and an effect for blocks by overall seconds by frequency, $\underline{F}(16, 96) = 2.44$, $\underline{p} < .025$, when all 11 subjects were included in the analysis. Thus it was confirmed with a larger number of trials, that the occurrence of dishabituation in this experiment depends on frequency.

In conclusion, the results of both subgroups indicated that dishabituation is frequency specific. In addition, the data of subjects who remained in a satisfactory state throughout the experiment showed that the switch from 1600 Hz to 1000 Hz is more likely to lead to dishabituation than the reverse.

APPENDIX F

TABLES

Table 1. Results not mentioned in the text.

Trial #	Subject Characteristics	between subject factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
2,4; 3,5	all 20 subjects	age, sex, frequency	blocks, trials, seconds	-.5 to +15.5	4.91	.0467	1, 12	linear seconds by age
					5.78	.0333	1, 12	linear seconds by age by sex
					19.89	.0008	1, 12	quadratic seconds
					7.46	.0182	1, 12	cubic seconds
					5.21	.0002	16, 192	overall seconds
					2.59	.0253	16, 192	interaction of overall seconds by sex
					6.68	.0000	16, 192	blocks by overall seconds
					3.28	.0092	16, 192	blocks by overall seconds by sex
					11.68	.0051	1, 12	linear blocks by linear trials by cubic seconds by sex by frequency interaction
1, 3, 5	all 20 subjects	age, sex, frequency	trials, seconds	-.5 to + 15.5	11.07	.0001	16, 192	overall seconds
					2.56	.0319	16, 192	overall seconds by sex
1, 3, 5	10 male subjects		trials, seconds	-.5 to +15.5	9.10	.0003	16, 144	overall seconds
1, 3, 5	10 female subjects		trials, seconds	-.5 to +15.5	4.41	.0156	16, 144	overall seconds

Table 1. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
1	20 subjects	sex, frequency	seconds	-.5 to +15.5	4.53	.0017	16,256	overall seconds
3	20 subjects	sex, frequency	seconds	-.5 to +15.5	7.22	.0001	16, 256	overall seconds
5	20 subjects	sex, frequency	seconds	-.5 to +15.5	3.74	.0082	16, 256	overall seconds
					7.79	.0131	1, 16	cubic seconds by sex by frequency
4	male subjects	frequency	seconds	-.5 to +15.5	2.68	.0161	16, 128	overall seconds by frequency
2,4; 3,5	10 subjects tested with continuous tones, 10 with pulsed tones	age, sex, pulsing	blocks, trials, seconds	-.5 to +8.5	4.67	.0497	1, 12	linear seconds by age
					4.81	.0488	1, 12	linear seconds by sex
					5.16	.0423	1, 12	quadratic seconds
					5.85	.0323	1, 12	cubic seconds by age
					6.23	.0281	1, 12	cubic seconds by pulsing
					8.59	.0126	1, 12	cubic seconds by age by sex by pulsing
					3.57	.0076	9, 108	overall seconds by age
					3.56	.0036	9, 108	blocks by overall seconds by pulsing

Table 1. continued

Trial #	subject characteristics	between subject factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
					2.80	.0264	9, 108	overall seconds by sex
					6.01	.0002	9, 108	overall seconds by pulsing
					12.17	.0045	1, 12	linear blocks by linear trials by cubic seconds by sex by pulsing
					5.67	.0347	1, 12	blocks by pulsing
3, 5	continuous	age,	trials,	-.5 to +8.5	16.55	.0016	1, 12	main effect for trials
	versus	sex,	seconds		7.01	.0000	9, 108	overall seconds by pulsing
	pulsed	pulsing			5.58	.0359	1, 12	linear trials by cubic seconds by sex by pulsing
					3.71	.0040	9, 108	overall seconds by sex
2,4; 3,5	continuous	sex	blocks,	-.5 to +8.5	5.58	.0458	1, 8	main effect for blocks
	tones		trials,		9.22	.0161	1, 8	quadratic seconds
			seconds		14.30	.0054	1, 8	blocks by trials by linear seconds
					5.59	.0456	1, 8	blocks by trials by cubic seconds
					23.82	.0012	1, 8	blocks by trials by cubic seconds by sex
					4.62	.0048	9, 72	blocks by trials by overall seconds

Table 1. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
3, 5	continuous tones	sex	trials, seconds	-.5 to +8.5	7.53	.0253	1, 8	main effect for trials
					11.35	.0098	1, 8	linear trials by linear seconds
					8.16	.0213	1, 8	linear trials by cubic seconds
					3.69	.0200	9, 72	trials by overall seconds
2,4; 3,5	continuous tones		blocks, trials, seconds	-.5 to +8.5	6.22	.0342	1, 9	main effect for blocks
					9.86	.0119	1, 9	quadratic seconds
					16.04	.0031	1, 9	linear blocks by linear trials by linear seconds
					4.32	.0059	9, 81	blocks by trials by seconds
8, 10, 12, 14	15 subjects	sex, frequency	trials, seconds	-.5 to +15.5	8.13	.0158	1, 11	cubic trials by linear seconds by sex by frequency
					6.69	.0253	1, 11	cubic trials by cubic seconds
					6.38	.0282	1, 11	cubic trials by cubic seconds by sex
					5.32	.0416	1, 11	cubic trials by cubic seconds by frequency
					9.79	.0096	1, 11	cubic trials by cubic seconds by sex by frequency
					1.73	.0317	48, 528	trials by seconds by frequency
					1.91	.0136	48, 528	trials by seconds by sex by frequ.

Table 1. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
8, 10, 12	17 subjects	sex, frequency	trials, seconds	-.5 to +15.5	11.62	.0047	1, 13	quadratic trials by linear seconds by frequency
					7.90	.0147	1, 13	quadratic trials by linear seconds by sex by frequency
					5.71	.0328	1,13	quadratic trials by quadratic seconds
					7.79	.0153	1, 13	quadratic trials by cubic seconds by sex
					2.03	.0383	32, 416	trials by seconds by frequency
					2.11	.0310	32, 416	trials by seconds by sex by frequency
9, 11 13	16 subjects	sex, frequency	trials, seconds	-.5 to +15.5	5.07	.0438	1, 12	linear trials by quadratic seconds by frequency
					4.88	.0473	1, 12	linear trials by cubic seconds by sex by frequency
6	20 subjects	age, sex, frequency	seconds	-.5 to +15.5	3.04	.0108	16, 192	overall seconds by age by sex

Table 1. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
6	5 older females		seconds	-.5 to +15.5	2.93	.0108	16, 64	overall seconds
26	4 subjects at 1600 Hz	sex	seconds	-.5 to +15.5	6.93	.0000	16, 32	overall seconds
					6.80	.0000	16, 32	overall seconds by sex
26	12 subjects	sex, frequency	seconds	-.5 to +15.5	3.64	.0086	16, 128	overall seconds
					4.08	.0045	16, 128	overall seconds by frequency
					3.99	.0051	16, 128	overall seconds by sex by frequency
19, 21	8 subjects	sex, frequency	trials, seconds	-.5 to +15.5	2.98	.0129	16, 64	trials by overall seconds by frequency
21	8 subjects	sex, frequency	seconds	-.5 to +15.5	2.52	.0309	16, 64	overall seconds
					4.67	.0008	16, 64	overall seconds by frequency
21	4 subjects at 1000 Hz**		seconds	-.5 to +15.5	4.17	.0033	16,48	overall seconds
19, 21	11 subjects	sex, frequency	trials, seconds	-6.5 to -.5	3.25	.0112	16, 112	trials by overall seconds by frequency

Table 1. continued

Trial #	subject characteristics	between subjects factors	within subjects factors	range of seconds examined	F-value	p-value	degrees of freedom	source
17, 19, 21, 23	8 subjects	sex, frequency	blocks, trials, seconds	-.5 to +15.5	21.02	.0101	1, 4	blocks by cubic seconds by sex
					2.68	.0470	16, 64	blocks by overall seconds by frequency
					41.94	.0029	1, 4	blocks by trials by cubic seconds by frequency
17, 19, 21, 23	11 subjects	sex, frequency	blocks, trials, seconds	-.5 to +15.5	11.87	.0137	1, 6	blocks by cubic seconds by sex
					19.16	.0047	1, 6	blocks by trials by cubic seconds by frequency
19, 21	12 subjects	sex, frequency	trials, seconds		2.91	.0362	6, 54	trials by overall seconds by sex by frequency
19, 21 23, 25	8 subjects	sex, frequency	blocks, trials, seconds	-6.5 to -.5	17.37	.0141	1, 4	blocks by trials by frequency
					9.61	.0362	1, 4	blocks by trials by sex by frequency
					10.69	.0308	1, 4	cubic seconds
					19.38	.0117	1, 4	cubic seconds by sex
					14.22	.0196	1, 4	cubic seconds by frequency
					29.65	.0055	1, 4	linear trials by linear seconds by sex
					2.65	.0407	6, 24	blocks by trials by seconds by sex

Table 1. continued

Trial #	subject characteristics	between subjects factor	within subject factor	range of seconds examined	F-value	p-value	degrees of freedom	source
23, 25	4 male subjects	frequency	trials, seconds	-6.5 to -.5	105.79	.0093	1, 2	linear trials by linear seconnds
					22.61	.0000	6, 12	trials by overall seconds
					4.978	.0089	6, 12	trials by overall seconds by frequency
25	8 subjects		seconds	-.5 to +15.5	3.31	.0029	16, 112	overall seconds

** Starting frequency

Table 2. Main effects of sex and frequency.

Trial #	subject characteristics	between subject factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
2,4; 3,5	20 subjects	age, sex frequency	blocks, trials, seconds	-.5 to + 15.1	9.81	.0087	1, 12	sex
					5.63	.0352	1, 12	frequency
1, 3, 5	20 subjects	age, sex frequency	trials, seconds	-.5 to + 15.5	18.54	.0010	1, 12	sex
					9.81	.0087	1, 12	frequency
1	20 subjects	sex, frequency	seconds	- .5 to + 15.5	26.18	.0001	1, 16	sex
					17.56	.0007	1, 16	frequency
3	20 subjects	sex, frequency	seconds	-.5 to + 15.5	15.87	.0011	1, 16	sex
					9.66	.0068	1, 16	frequency
5	20 subjects	sex, frequency	seconds	-.5 to +15.5	1.29	.0040	1, 16	sex
2, 4	20 subjects	age, sex, frequency	trials, seconds	-.5 to +15.5	6.29	.0275	1, 12	sex

Table 2. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
2	10 male subjects	frequency	seconds	-.5 to +15.5	9.38	.0155	1, 8	frequency
3, 5	10 continuous 10 pulsed	age, sex, pulse rate	trials, seconds	-.5 to +15.5	5.49	.0371	1, 12	sex by pulse rate interaction
8	19 subjects	sex, frequency	seconds	-.5 to +15.5	6.20	.0250	1, 15	sex
					5.83	.0290	1, 15	frequency
8, 10, 12, 14	15 subjects	sex, frequency	trials, seconds	-.5 to +15.5	23.47	.0005	1, 11	sex
					19.88	.0010	1, 11	frequency
8, 10 12	17 subjects	sex, frequency	trials, seconds	-.5 to +15.5	7.96	.0144	1, 13	sex
					7.75	.0155	1, 13	frequency
9, 11 13	16 subjects	sex, frequency	trials, seconds	-.5 to +15.5	16.38	.0016	1, 12	sex
					10.63	.0068	1, 12	frequency

Table 2. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
7	20 subjects	age, sex, frequency	seconds	-.5 to +15.5	5.79	.0332	1, 12	frequency
25	8 subjects	sex, frequency	seconds	-.5 to +15.5	25.99	.0070	1, 4	sex
7	8 subjects	sex, frequency	seconds	-.5 to +15.5	10.09	.0336	1, 4	sex
19, 21	8 subjects	sex, frequency	trials, seconds	-.5 to +15.5	13.09	.0224	1, 4	sex
19	8 subjects	sex, frequency	seconds	-.5 to +15.5	9.93	.0345	1, 4	sex
21	8 subjects	sex, frequency	seconds	-.5 to +15.5	12.00	.0257	1, 4	sex
19	11 subjects	sex, frequency	seconds	-.5 to +15.5	22.28	.0022	1, 7	sex
					12.45	.0096	1, 7	frequency

Table 2. continued

Trial #	subject characteristics	between subjects factors	within subject factors	range of seconds examined	F-value	p-value	degrees of freedom	source
21	11 subjects	sex, frequency	seconds	-.5 to +15.5	13.34	.0082	1, 7	sex
17, 19, 21, 23	8 subjects	sex, frequency	blocks, trials, seconds	-.5 to +15.5	19.70	.0113	1, 4	sex
17, 19, 21, 23	11 subjects	sex, frequency	blocks, trials, seconds	-.5 to +15.5	17.64	.0057	1, 6	sex
19, 21	8 subjects	sex, frequency	trials, seconds	-6.5 to -.5	10.51	.0316	1, 4	sex
19, 21	12 subjects	sex, frequency	trials, seconds	-6.5 to -.5	8.13	.0190	1, 9	sex
19, 21; 23, 25	8 subjects	sex, frequency	trials, seconds	-6.5 to -.5	9.35	.0377	1, 4	sex

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BIOGRAPHICAL SCETCH

Margarete Boettcher Davies was born on June 10, 1957, as daughter of Dr. Wilhelm Boettcher and Mrs. Caecilia Boettcher in Bonn, West Germany. She received the degree of Vordiplom fuer Psychologen from the Rheinische Friedrich Wilhelms Universitaet in 1978, and the degree of Master of Science from the University of Florida in 1982 under the supervision of Dr. W. Keith Berg.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

W. Keith Berg

W. Keith Berg, Chairman
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Wilse Webb

Wilse B. Webb
Graduate Research Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Scott A. Miller

Scott A. Miller
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Barbara G. Melamed

Barbara G. Melamed
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James Algina

James J. Algina
Associate Professor
of Foundations of Education

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1985

Dean, Graduate School